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BIOLOGY OF THE NORTHERN PIKE, ESOX LUCIUS LINNAEUS, IN THE WOOD RIVER LAKES SYSTEM OF ALASKA, WITH EMPHASIS ON LAKE ALEKNAGIK.

UNIVERSITY OF ALASKA, M.S., 1979

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BIOLOGY OF THE NORTHERN PIKE, *ESOX LUCIUS* LINNAEUS, IN THE WOOD RIVER LAKES SYSTEM OF ALASKA, WITH EMPHASIS ON LAKE ALEKNAGIK

A

THESIS

Presented to the Faculty of the
University of Alaska in partial fulfillment
of the Requirements
for the Degree of

MASTER OF SCIENCE

By

Michael B. Chihuly, B. S.

Fairbanks, Alaska

May, 1979

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BIOLOGY OF THE NORTHERN PIKE, ESOX LUCIUS LINNAEUS,

IN THE WOOD RIVER LAKES SYSTEM OF ALASKA,

WITH EMPHASIS ON LAKE ALEKNAGIK

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In memory of my father,

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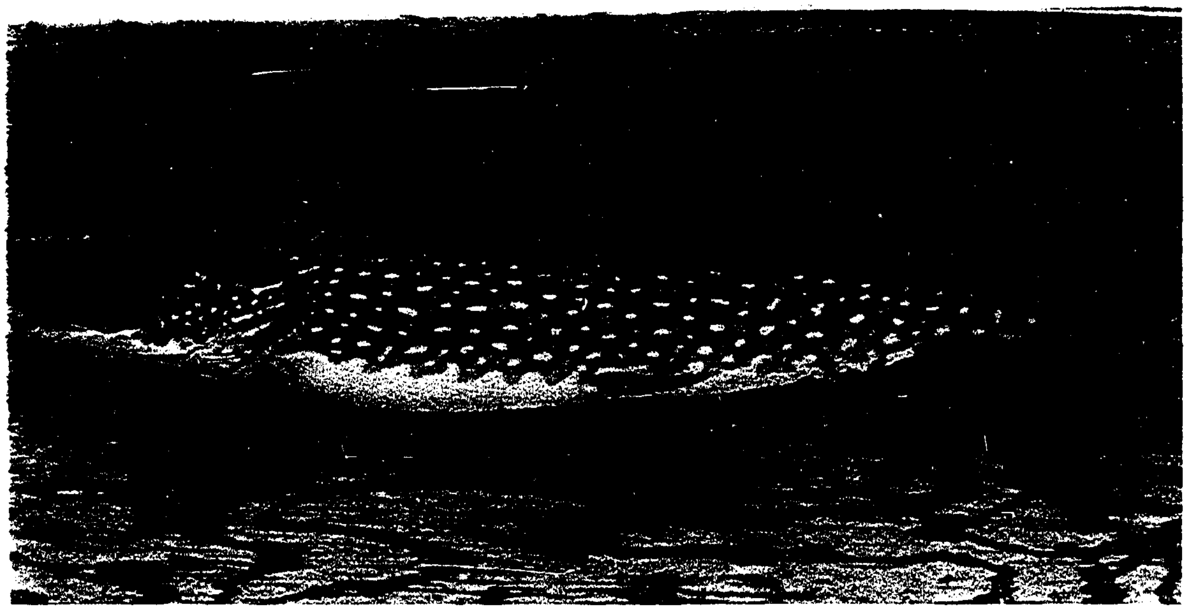

A northern pike, Esox lucius Linnaeus, from Lake Aleknagik, Alaska.

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ABSTRACT

This study sought basic biological information about northern pike of the Wood River Lakes system with emphasis on Lake Aleknagik, and focused on population structure, habitat, movement and food habits.

Opercular bones were used for age and back-calculated growth determinations. Growth of pike was slow with the greatest increment occurring in the first year of life. After age 4^+, growth remained constant at about 25 mm per year.

Pike habitat was optimal when water was brown, relatively warm and shallow and contained dense stands of aquatic vegetation rooted in a muddy bottom. Less than five percent of the total surface area of the system included pike habitat. Pike homed to spawn in the spring and then remained relatively sedentary during summer months.

The food of large pike (200 - 1,000 mm) consisted primarily of blackfish and threespine stickleback. Stickleback fry and mayfly nymphs were the most important foods of medium pike (50 - 199 mm).

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ACKNOWLEDGEMENTS

I would like to express my appreciation to Dr. John Clark, Lou Gwartney and Chuck Meachum Jr., fisheries biologists for the Alaska Department of Fish and Game, for their encouragement, field support and critical reading of the thesis.

My appreciation and thanks also go to Karen Tony, Bill Baechler, Fred DeCicco and Larry Aumiller for their support and dedication to this project while in the field.

I would like to give special thanks to John Burke and my assistant George Hornberger. Their hard work, encouragement and knowledge contributed greatly to this project.

I would like to express my appreciation to Ken Alt, Dr. Sam Harbo, Dr. Ron Smith and especially Dr. James Morrow for their time and support.

Love and gratitude are given to my wife Shirley for her patience and understanding during this project.

This research was funded through a contract from the Alaska Department of Fish and Game to the University of Alaska.

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INTRODUCTION

The Northern Pike

The northern pike, *Esox lucius* Linnaeus, belongs to the Family Esocidae, in which there is one genus of five species. One species is endemic to Siberia, while three others are found only in eastern North America. Distribution of the northern pike is circumpolar in the northern hemisphere. A subspecies of the northern pike, *Esox lucius baicalensis* Dybowski, is recognized from Siberia. The pikes are known from the Middle Eocene to Recent in Eurasia and Pliocene to Recent in North America.

There are at least two morphological forms of northern pike in North America, characterized by mean differences in vertebral counts and dorsal, anal, pectoral and pelvic fin ray counts. The differences are about what might be expected from two widely separated populations and are probably attributable to isolation in widely separated glacial refuges.

The northern pike has a long laterally compressed body with the greatest body depth occurring between the dorsal and anal fins. The dorsal fin is positioned far back on the body and originates slightly in advance of the anal fin. The head of the pike is long and flattened much like a duck bill. There are large canine teeth on the dentary and numerous, but smaller, well developed teeth on the premaxilla, head and shaft of the vomer, palatines, tongue and basibranchials.

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The under surface of the lower jaw possesses five mandibular pores on each side (rarely varies) and the lower jaw often projects beyond the snout. The scales of the pike are cycloid and moderately small. The intestine is long and undifferentiated. There are no pyloric caeca. The pikes are physostomous.

The northern pike can be most easily distinguished from other North American species of the genus by the presence or absence of scales on the cheeks and opercula. In the northern pike, the cheeks are fully scaled while only the upper half of the operculum is scaled. Neither the cheeks nor the opercula are fully scaled (upper half only) in the muskellunge but both are fully scaled in the pickerels.

Adult northern pike vary in color from dark green or brown to brilliant green through olive-green on the dorsal and upper sides of the head and body. The lower sides are lighter in color and the belly varies from yellow to milk white. The flanks are marked with roughly longitudinal rows of yellow to white bean-shaped spots. The fins are orange to red and are marked with dark blotches or bars. In juveniles (usually less than 25 cm), the flanks are marked with pale vertical bars that later break up into the rows of spots characteristic of the adults. The body of the northern pike often appears to be flecked with gold. This is due to the tiny spot of gold pigment on the outer exposed edge of most scales.

The silver pike, a mutant form of the northern pike, possesses strikingly different coloration. It lacks the vertical bars or pale spots and dark background of the normally colored pike. Rather, its

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dorsal surface and sides vary from metallic blue and green to bright silver. It often retains the gold flecking on the body that is characteristic of the species.

Some morphological characteristics of the silver pike such as eye diameter, interorbital width and length of the mandible and maxillary, also appear to differ from the normal northern pike. Eddy and Underhill (1974) reported that the silver pike is a true breeding mutant and has established itself in several lakes breeding with others of its kind. Lawler (1960) found that the silver pike comprised only 0.2% of the pike population of Heming Lake, Manitoba. He concluded that because of its scarcity, the silver pike was not breeding with others of its kind. Occasionally pike were captured in Heming Lake that had color and markings characteristic of both forms. These pike were recorded as silver pike X normal pike hybrids.

Silver pike in Alaska were first reported by Bartholomew, Divall and Morrow (1962) from the mouth of the Kandik River on the Yukon. A number of silver pike as well as silver X normal hybrids were captured in the Wood River Lakes system during the present study. The silver pike is now known to occur sporadically throughout the world distribution of the northern pike.

Northern pike inhabit primarily freshwaters but are also found in slightly brackish waters. In the Baltic Sea off the coast of Sweden, northern pike support an important commercial fishery.

Northern pike occur naturally throughout most of Alaska. They are absent from the lower Alaska Peninsula and the Aleutian Islands,

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parts of Southcentral Alaska and Southeast Alaska. Recent illegal and unwanted introductions of this species into Upper Cook Inlet and the Kenai Peninsula have helped to spread its range.

In Alaska, the northern pike is becoming an increasingly important game fish. Its popularity is spreading to much of the State, reaching a peak in Interior Alaska where the pike is highly prized. Until recent times, sport angling pressures have been light and pike populations are healthy. There are no closed seasons and no limit on northern pike in Alaska, except in the Tanana River drainages where the daily bag and possession limit is ten fish. Not more than two (2) of the ten fish limit may be over 30 inches in length. Trophy fish awards are issued by the Alaska Department of Fish and Game to anglers who catch northern pike meeting the minimum weight qualification (15 lb).

In many areas of Alaska, the northern pike is used mainly for dog food and subsistence purposes.

Past research on northern pike populations in Alaska has been relatively limited. Major studies have been carried out by the Alaska Department of Fish and Game in the Minto Flats and a few Interior Alaskan lakes. The Department is also investigating pike populations on the Kenai Peninsula due to recent introductions there. Other pike data collected in the state are primarily related to catalog and inventory programs or incidental to other studies. Increased utilization of northern pike in Alaska will demand further research on this species.

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Study Area

The present study was confined to the Wood River Lakes system near Bristol Bay in southwest Alaska (Fig. 1). This system is encompassed by approximate coordinates from 58° to 60° N Latitude and from 158° to 160° W Longitude. The major lakes from north to south are Grant Lake, Lake Kulik, Lake Beverley, Lake Nerka, Little Togiak Lake and Lake Aleknagik. The Wood River Lakes are elongated, roughly parallel and lie in an east-west direction, bounded on the west by the Wood River Mountains, to the north and east by the Nushagak Lowlands and to the south by Bristol Bay. They are interconnected by short rapid rivers and drain into Bristol Bay via the Wood and Nushagak rivers. The lakes are glacial in origin and occupy u-shaped bedrock basins. They are typically oligotrophic and show distinct thermal stratification during the summer months. The Wood River Lakes have a combined surface area of 425 km^2. They are generally ice free from June through November.

Lake Aleknagik is the southernmost lake in the Wood River Lakes system. It has a maximum length of 32 km (20 mi) and a mean width of 2.6 km (1.6 mi). Its maximum depth is 110 m (361 ft) and its mean depth is 43 m (141 ft). Its shores are primarily precipitous with limited littoral and shelf areas.

The village of Aleknagik is situated on the southeast end of Lake Aleknagik (Fig. 2). Its population in the last census was 225. Dillingham lies just south of Aleknagik and had an estimated population in early 1978 of 1,269. Dillingham is connected to Aleknagik by road.

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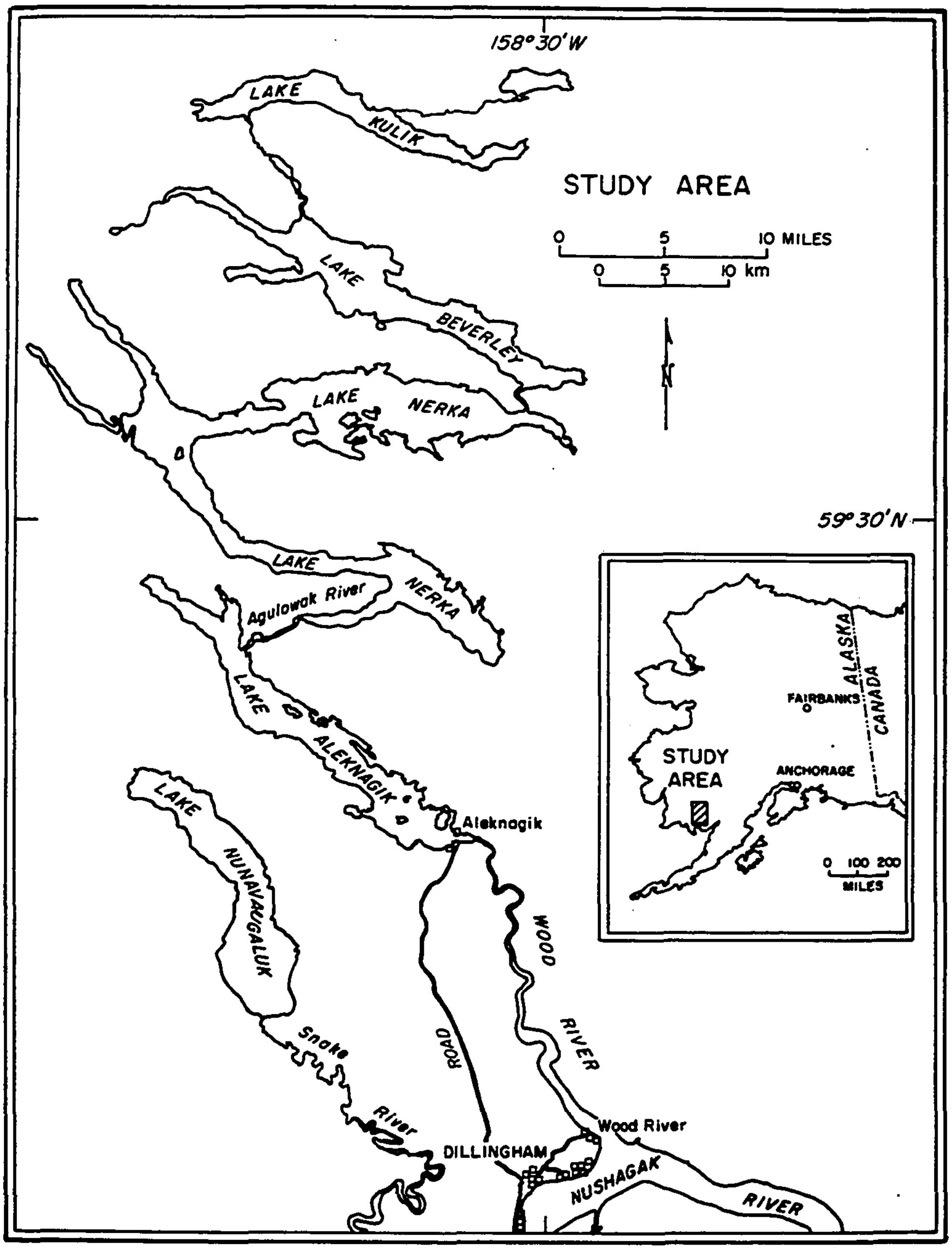

Figure 1. Map of the Wood River Lakes system in southwest Alaska.

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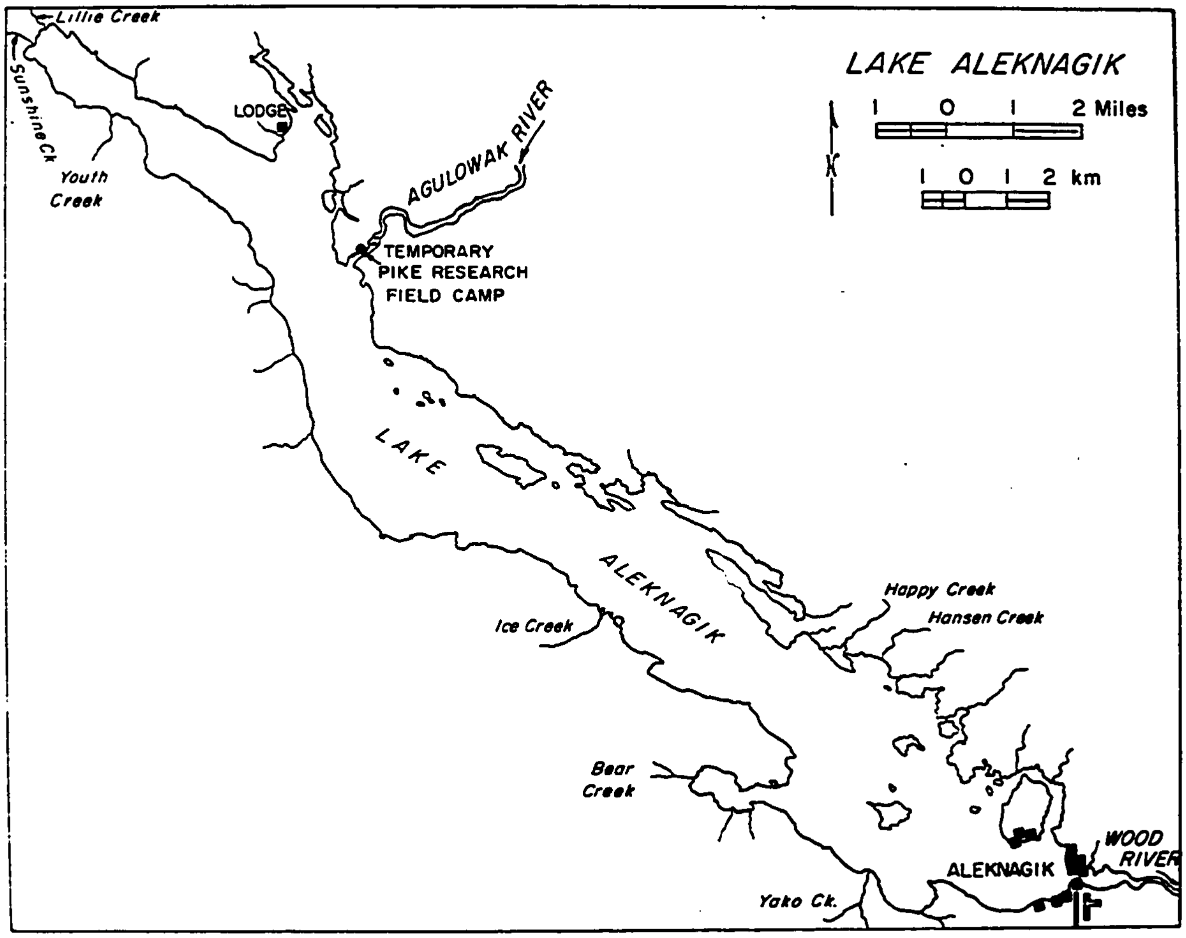

Figure 2. Map of Lake Aleknagik showing the location of the village of Aleknagik, a commercial sport angling lodge and the temporary field camp used in this study. Lake Aleknagik was the primary study area.

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Travel within the Wood River Lakes system is primarily by boat or amphibious aircraft in the summer and by snow machine in the winter.

Three commercial lodges are presently operating in the system, catering primarily to non-resident sport anglers. All northern pike research activities were based from a temporary field camp located near the mouth of the Agulowak River.

All species of fishes found in the Wood River Lakes, according to Nelson (1966), are listed as follows:

Scientific name	Common name
Lampetra japonica	Arctic lamprey
Lampetra tridentata	Pacific lamprey
Coregonus pidschian	Humpback whitefish
Prosopium coulteri	Pigmy whitefish
Prosopium cylindraceum	Round whitefish
Oncorhynchus gorbuscha	Pink salmon
Oncorhynchus keta	Chum salmon
Oncorhynchus kisutch	Coho salmon
Oncorhynchus nerka	Sockeye salmon
Oncorhynchus tshawytscha	Chinook salmon
Salmo gairdneri	Rainbow trout
Salvelinus alpinus	Arctic char
Salvelinus malma	Dolly varden
Thymallus arcticus	Arctic grayling
Hypomesus olidus	Pond smelt
Osmerus dentex	Arctic smelt
Dallia pectoralis	Alaska blackfish
Esox lucius	Northern pike
Lota lota	Burbot
Gasterosteus aculeatus	Threespine stickleback
Pungitius pungitius	Ninespine stickleback
Cottus cognatus	Slimy sculpin
Platichthys stellatus	Starry flounder

In a study of the relative abundance and distribution of fish species in Lake Aleknagik, Rogers, Nelson, Pella and Burgner (1963) found the threespine stickleback to be the most abundant of the small resident

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fishes. Gillnet catches showed that the arctic char was the most abundant of the large resident fishes.

Purpose and Funding

According to a legislative report distributed by the Commercial Fisheries Division of the Alaska Department of Fish and Game (unpublished, 1975), a long term decline of sockeye salmon stocks produced in the Wood River Lakes of Bristol Bay has been extensively documented. Increased escapement of returning adults has not produced larger runs in subsequent cycle years. Some factor other than the number of parent spawners is apparently suppressing sockeye salmon production in the Wood River Lakes.

The 1974-75 Alaskan Legislature appropriated $600,000 for enhancement and rehabilitation of sockeye salmon stocks in these lakes. These monies provided for a multi-faceted research program and management implementation that focused on increasing sockeye salmon production by increasing smolt numbers or producing healthier smolt.

The sockeye salmon is a second intermediate host of the parasitic tapeworm, *Triaenophorus crassus*, the history of which is well documented in the Wood River Lakes system. It has been reported by the College of Fisheries, University of Washington, staff that the survival of sockeye smolt infected with the plerocercoid larvae is less than survival of unparasitized smolt. Furthermore, the incidence of parasitism approaches and perhaps exceeds 50% of all sockeye smolts produced in the Wood River Lakes.

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Triaenophorus crassus resides as an adult in the intestine of the northern pike (Miller, 1952). It matures and releases eggs in the spring during the northern pike spawning period. The eggs hatch in the water and release coracidia which are ingested by cyclopoid copepods of the genus *Cyclops*. Infected *Cyclops*, when eaten by a member of the Family Salmonidae, primarily sockeye salmon in the Wood River system, infect these fish and become encysted in their flesh. The cycle is completed when the northern pike consumes an infected salmonid.

The infection rate of northern pike by *T. crassus* in the Wood River Lakes system approaches 100%. The northern pike is a specific host for the parasite and without northern pike, the parasite would disappear. An obvious management option, then, would be the eradication or reduction of the pike population as a means of parasite control. Elimination or reduction of the parasite *T. crassus* could lead to larger, healthier and perhaps more numerous sockeye smolts migrating from the Wood River Lakes.

Evaluation of such a management scheme requires important biological information. Prior to 1975, very little was known about northern pike in the Wood River Lakes system. This study sought basic biological information about northern pike with emphasis on population structure, habitat and distribution, movement and stomach analysis. It is hoped that this initial information will provide the groundwork for future research and evaluation of management plans.

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AGE AND GROWTH

Introduction

The age and growth of the northern pike, *Esox lucius* Linnaeus, has been determined by a variety of methods including the use of length frequencies, scales, otoliths, vertebrae, fin rays and opercular bones. All of these methods have their shortcomings and the advantages and disadvantages of each must be considered and applied to the anticipated conditions of study before a suitable method can be chosen.

Scales are the most widely used age and growth determinants for northern pike throughout the world. Williams (1955) determined that the annulus of the scale is a valid year mark for northern pike. He identified, however, three types of false annuli that may occur. These are: 1) an abrupt change in growth rate early in the first summer of life that may take the form of a false annulus, 2) spawning may cause false annuli if the annulus normally forms before that time, 3) many pike after their first year of life form false annuli during midsummer. Williams went on to describe three scale-growth relationships that may occur in pike: 1) scales are difficult to interpret in areas where pike are growing slowly, whether false annuli occur or not; 2) in areas where pike growth is average, scales may be easy to read if false annuli do not occur and difficult if they do occur; and 3) in those areas where growth is rapid, scales are easy to interpret even when false annuli occur because these annuli are easily

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distinguished. He concluded that, if false annuli can be identified and the nature of true annuli recognized, then all pike can be aged accurately except those from slow growing populations.

Other researchers, such as Runnstrom (1954), Ridenhour (1957), Frost and Kipling (1959), Casselman (1967), Vasey (1974), Craig (1975) and Alt (1978) have experienced difficulty with reading scales from the northern pike they studied. Cheney (1971) concluded that it was difficult to age northern pike in Alaska by scales. Cheney (1972) critically reexamined the use of scales for age determination of Alaskan northern pike from the Minto Flats and concluded that they could be utilized for pike ages 0^+ through 5^+. He found scales from northern pike at George, Healy, East Twin and West Twin Lakes in Alaska easier to read with the annuli more distinct.

A review of the literature suggested that the use of scales might present difficulties when trying to determine the age and growth of northern pike in the Wood River Lakes system of Alaska. Therefore, scales, otoliths, vertebrae and opercular bones were collected from northern pike in Lake Aleknagik during the 1975 field season (May to August) and examined later that year for usefulness as age and growth indicators.

Scales from Lake Aleknagik northern pike were difficult to interpret and false annuli were numerous; hence, they were rejected. Growth rings on otoliths were clear and distinct but preparation of the bones proved to be time-prohibitive. Otoliths of the northern pike are large and thick and must be ground thin before they can be read.

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Otoliths are rejected for the primary age and growth studies. Cheney (1971) investigated the use of dorsal fin rays for Alaskan northern pike and found them to have some advantages over scales, but their preparation was time consuming and required complex instruments. Fin rays were rejected. Vertebrae were examined and appeared to be good indicators of age. Cheney (1972) preferred vertebrae to scales, concluding that they were easier to interpret and less subject to the formation of false annuli. Vertebrae became a possible alternative. Length frequencies of northern pike from Lake Aleknagik yielded a typical bell-shaped distribution reflecting sampling bias. Length frequencies were not useful for age determination.

Le Cren (1947) concluded that the opercular bone was a good method for ascertaining the age and growth of the perch, Perca fluviatilis. Following Le Cren, Frost and Kipling (1959) validated the use of opercular bones as age and growth (but not age without growth) indicators for northern pike of Lake Windermere, England. This was the first time opercular bones had been utilized for this species. Since then, Mann (1976) has used opercular bones of northern pike for age and back-calculated growth determinations. Opercular bones of northern pike from Lake Aleknagik were critically examined and accepted as the most suitable method for this study.

Growth zones and annuli are clear and distinct on opercular bones of northern pike from the Wood River Lakes system. The crowded growth rings on the outer edge of the bone can still be seen clearly when the northern pike are very old. False annuli are not a problem with

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opercular bones, though they do occur. Back-calculations are precise owing to the distinct and clear annuli.

Opercular bones have two primary disadvantages. In order to collect the bones the northern pike must be sacrificed and there is also the problem of missing early annuli on the large thick bones of older northern pike.

Methods and Materials

All reference to fish length in the present paper is total length unless otherwise stated. Total length was measured from the anterior-most extremity (tip of snout or lower jaw) to the tip of the longest lobe of the caudal fin. The caudal fin was moved to a position of maximum length.

Otoliths were used to age 77 northern pike from Lake Aleknagik ranging from 94 mm to 836 mm in length. Preparation of otoliths for age determination was difficult and time consuming. Otoliths were removed by splitting the head and extracting with tweezers. Only the sagitta, the largest of the ear bones, were used. They were cleaned and stored in coin envelopes in a dry condition. After returning from the field, the otoliths were placed in rings of fluid epoxy that were temporarily attached to a teflon surface. Upon hardening of the epoxy, the rings were easily broken away from the teflon, exposing the concave surface of the otoliths for grinding. Fine grit on a wet grinding wheel was then used to wear the otolith sufficiently thin to be read. Otoliths were read on a dark background under reflected light with a binocular dissecting scope. Glycerin was used to enhance otolith clarity.

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Five-hundred and twenty-three northern pike from the Wood River Lakes system ranging in length from 15 mm to 974 mm were aged and their lengths at each annulus back-calculated using opercular bones. Four-hundred and one of these pike were from Lake Aleknagik, while 27, 34, 31 and 30 additional pike were taken from Little Togiak Lake, Lake Nerka, Lake Beverley and Lake Kulik respectively. No northern pike were sampled from Grant Lake and it is not known if northern pike exist there.

Little preparation was necessary in order to use opercular bones as age and growth indicators. The operculum was cut from the gill cover of the pike with a small pair of scissors. While still moist, it was immersed in boiling water; all muscle and viscera quickly separated from the bone. The bones were allowed to dry and could then be stored in coin envelopes indefinitely. Opercular bones are easily read only after they have thoroughly dried and clarity seems to improve the longer the drying period. They were read with the naked eye or a magnifying glass, and in the case of small bones, a binocular dissecting scope was used. Best results were obtained when the opercular bones were placed on a dark background under reflected light. For back-calculations, the bones were immersed in a small dish of xylene to enhance clarity and placed under a simple photographic enlarger. The enlarged image was projected on a piece of white paper on which the annuli were marked and the back-calculations made.

The direct proportion method was used for back-calculating lengths of northern pike from opercular bones. The formula is as follows:

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$l_n = \frac{s_n}{s} l$ where "l_n" = length of fish when annulus "n" was formed, "s_n" = length of operculum from origin to annulus "n", "s" = total length of operculum and "l" = length of the fish at the time the operculum was taken.

In order to compare mean annual growth increments of tagged pike recaptured one year later and tagged pike recaptured at varying time intervals after tagging (250 to 431 days), with mean annual growth increments as determined from opercular bones, it was necessary to assign an age to each fish at the time of tagging. Age was estimated according to length and based on back-calculated lengths as determined from opercular bones. A northern pike whose length at the time of tagging fell nearest an average back-calculated length for a given age class was assigned to that age class.

For tagged pike recaptured one year later, growth increments could be immediately plotted against age for growth comparison. A special adjustment of growth increments was necessary however, for tagged pike recaptured at varying time intervals after tagging.

Characteristic of freshwater fishes of northern latitudes, the northern pike displays rapid growth during the short summer period and very slow to no growth during the remainder of the year. The primary growing period for northern pike from Lake Aleknagik was estimated to be from June 20th to October 1st, based on spring "break-up", the peak of spawning activity, formation of the annulus on opercular bones and fall "freeze-up." This is 102 "primary growing days." Growth of pike during the remainder of the calendar year is believed to be slow and

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insignificant relative to the rapid growth occurring during the summer period. Annual growth increments of northern pike from Lake Aleknagik as determined from opercular bones are then primarily a result of the estimated 102 "primary growing days" occurring each year.

In order to equate annual growth increments determined from opercular bones with growth increments of tagged pike recaptured after varying periods of time, and hence, varying number of "primary growing days", growth increment since tagging (y axis), was regressed on "primary growing days" since tagging (x axis) for individuals of each estimated age class of tagged pike (Fig. 3). For age classes 3^+ through 10^+ I had sample sizes varying from 8 to 27. Correlation coefficients (r) of y on x ranged from .0787 to .7588 for the above age classes. Linear regression equations for each age class were then calculated and the annual growth increment identified for the entire 102 "primary growing days." These annual growth increments for each of the age classes of tagged northern pike are then equatable for comparison with the annual growth increments determined from opercular bones.

Results

Rapid summer growth is seen on the opercular bone as a broad, white, opaque zone when viewed with reflected light on a dark background. This white opaque zone fades to a watery white as a dark narrow transparent zone of winter growth is approached. This winter zone ends abruptly when another white opaque zone begins. It is this abrupt change that is accepted as the annulus. Transmitted light alters the color of the two zones.

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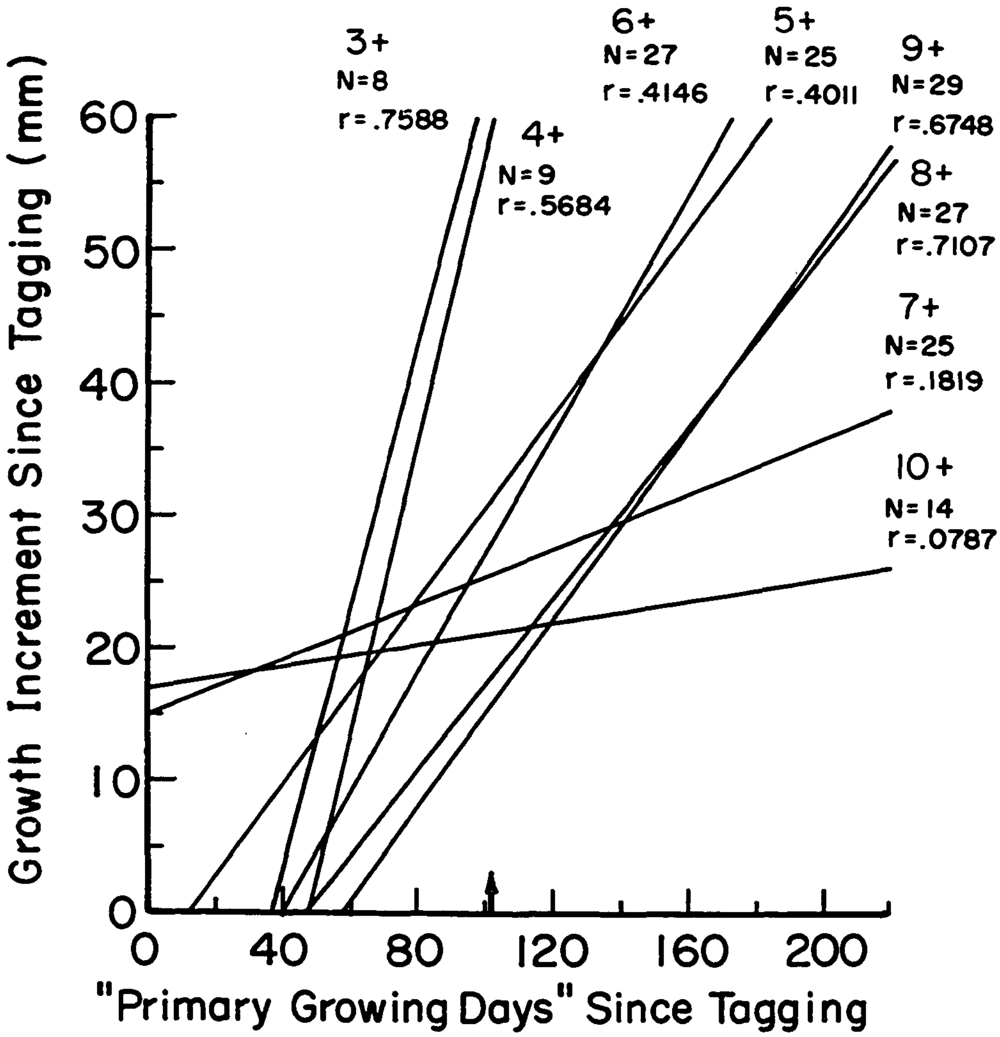

Figure 3. Growth of tagged northern pike from Lake Aleknagik by age class.

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Le Cren (1947) and Frost and Kipling (1959) both recognized the existence of false annuli on opercular bones. They are clearly distinguished from true annuli in that they begin and end abruptly within an opaque zone and there is no graduation of the white-opaque to dark-transparent. False annuli are more difficult to detect in large old fish.

The opercular bones of large pike become rather thick and discolored at the base as they enlarge. This thickening takes on a spongy, glutinous appearance as it fans out towards the outer edge of the bone. This discoloration and increased opacity of the bone makes the early annuli undiscernable. Thus, a false interpretation of age may be made. This problem is overcome by the use of the Walford plot described by Walford (1946). The Walford plot is a graph of "length at age $n + 1^{+}$" on "length at age n" and estimates the number of missing annuli and the lengths at these times. The Walford plot assumes that successive yearly increments added to length decrease in magnitude in geometric progression until a limiting value of total length is obtained. The age of the fish need not be known. Lengths are back-calculated from visible annuli and plotted in the above manner to give a regression whose y-intercept is the length at age 1^{+}. If this length corresponds with the last back-calculated length, then no annuli are missing. If the length does not correspond, then the equation is solved for length at age $n + 1^{+}$ until a comparable length is reached.

The Walford plot also gives an estimate of the ultimate length to be reached by a fish or a group of fishes. As the fish grows the

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"length at age n + 1^+" gets closer and closer to "length at age n" until unity is reached. This unity is the ultimate length. Figure 4 shows a Walford plot constructed from the back-calculated values of 387 northern pike from Lake Aleknagik. The ultimate length is given as 680 mm and the y-intercept of the regression corresponds well with the back-calculated value of length at age 1^+. The relationship of "length at age n + 1^+" on "length at age n" was found to be linear for individuals and means of individuals of northern pike from the Wood River Lakes system.

Frost and Kipling (1959) found that the opercular bones of pike up to 45 cm were easy to read because the bones were rarely thick enough to obscure annuli. The majority of the northern pike that they worked with, however, were greater than 45 cm and usually, but not always, had missing annuli. Walford plots were used to find missing annuli on the opercular bones of 60 northern pike from the Wood River Lakes system. Only two of the 60 northern pike were less than 45 cm.

Figure 5 shows the opercular bone of a female northern pike weighing 100 grams and captured with a dipnet June 27, 1976, in Lake Aleknagik. Aged at 2^+, this pike was 255 mm. Two annuli are clearly seen with considerable plus growth after the second annulus.

Figure 6 shows the opercular bone of a male northern pike weighing 1325 grams and captured in a gillnet August 3, 1976, in Little Togiak Lake. As determined by a Walford plot, this pike has one missing annulus which is estimated to have formed when the fish was 142 mm. This pike was 575 mm and is aged at 6^+.

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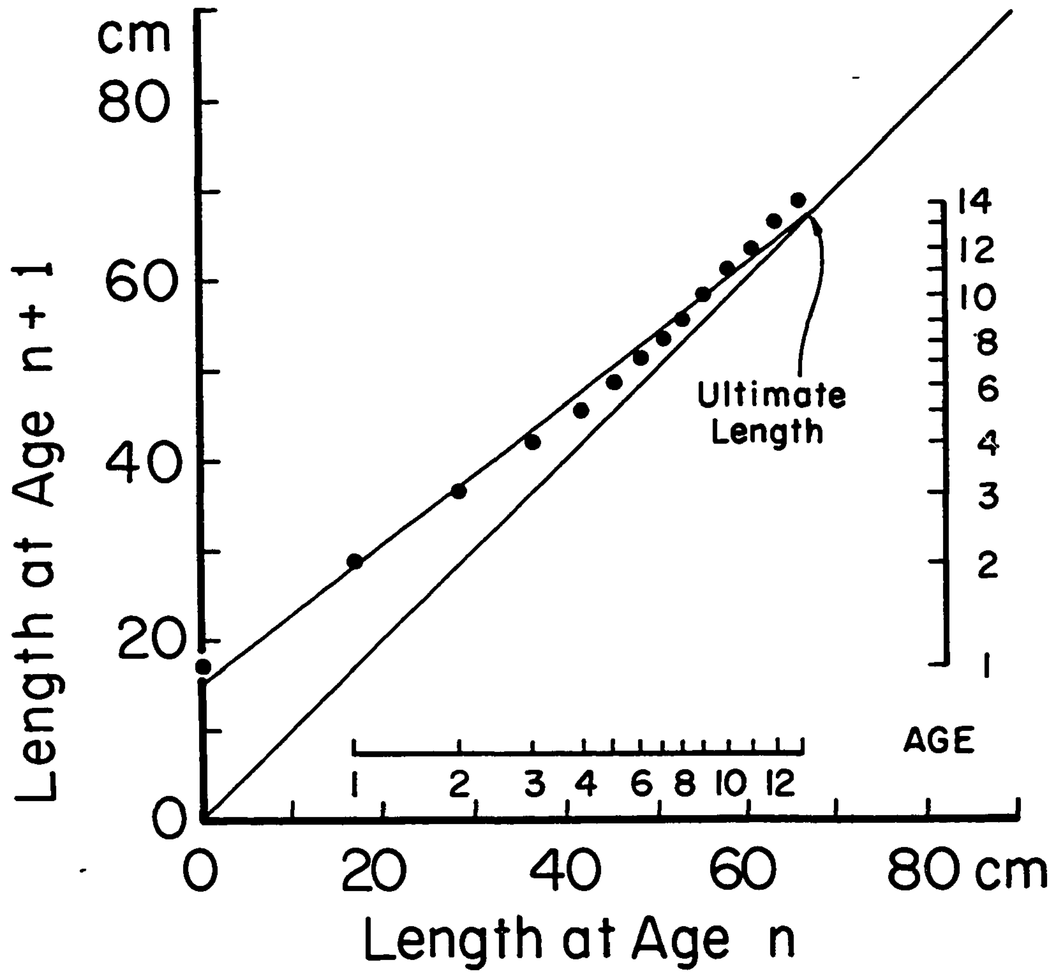

Figure 4. Walford plot constructed from the back-calculated lengths of 388 northern pike from Lake Aleknagik. The estimated ultimate length is 680 mm.

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Figure 5. The opercular bone of a northern pike from Lake Aleknagik. This pike was 255 mm in length and aged at 2^+. Two annuli are clearly seen with considerable plus growth after the second annulus.

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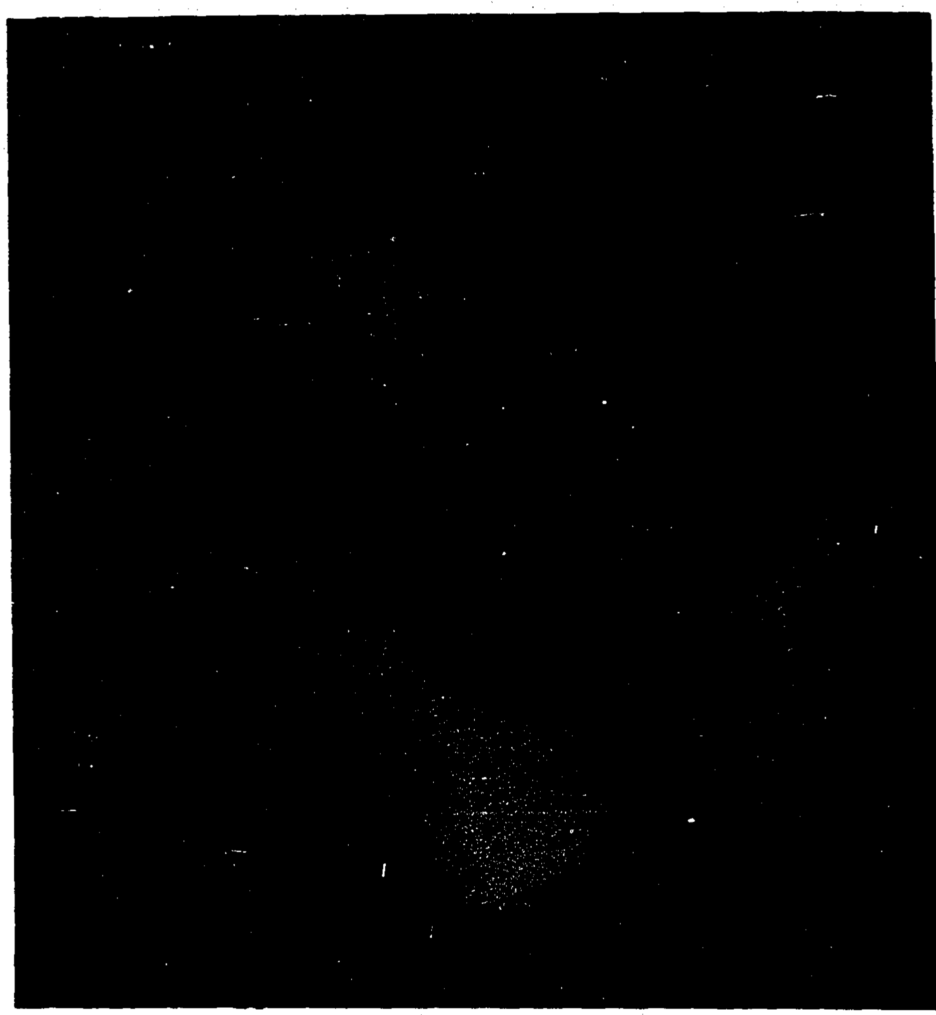

Figure 6. The opercular bone of a northern pike from Little Togiak Lake. As determined by a Walford plot, this pike has one missing annulus which is estimated to have formed when the fish was 142 mm. This pike was 575 mm in length and aged at 6^+.

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Figure 7 shows the opercular bone of a female northern pike weighing 4450 grams and captured in a gillnet August 6, 1976, in Lake Kulik. All annuli on this bone are clearly discernable with the naked eye, but due to the photographic process, two annuli have been lost in the thick basal portion of the bone. A Walford plot could be used to find these annuli. Aged at 14^{+}, this pike was 848 mm. Additional growth after the last annulus was formed is evident on the outer margin of the bone.

Of 24 northern pike sampled in Lake Aleknagik June 3rd through June 7th, 1976, 16% showed plus growth on the outer margin of the opercular bone while 83% showed no plus growth. Of 100 northern pike taken from Lake Aleknagik June 14th through June 23rd, 1976, 61% displayed plus growth while 39% showed no plus growth. After June 25th, all northern pike sampled in Lake Aleknagik showed plus growth. It is clear that the annulus on the opercular bone was formed in mid June of 1976.

One hundred total lengths of northern pike from Lake Aleknagik, ranging from 89 mm to 836 mm, were regressed on opercular bone lengths (projected images). The following relationship was established: ($r = .9954$), $Y = 11.87 + 3.07X$ where Y = total length of northern pike in mm and X = length of the opercular bone (projected image) in mm. Frost and Kipling (1959) determined that growth of the opercular bone and growth of northern pike from Lake Windermere was isometric and no correction was needed for length of the fish when the bone was formed. Mann (1976) determined that pike length and opercular size were related

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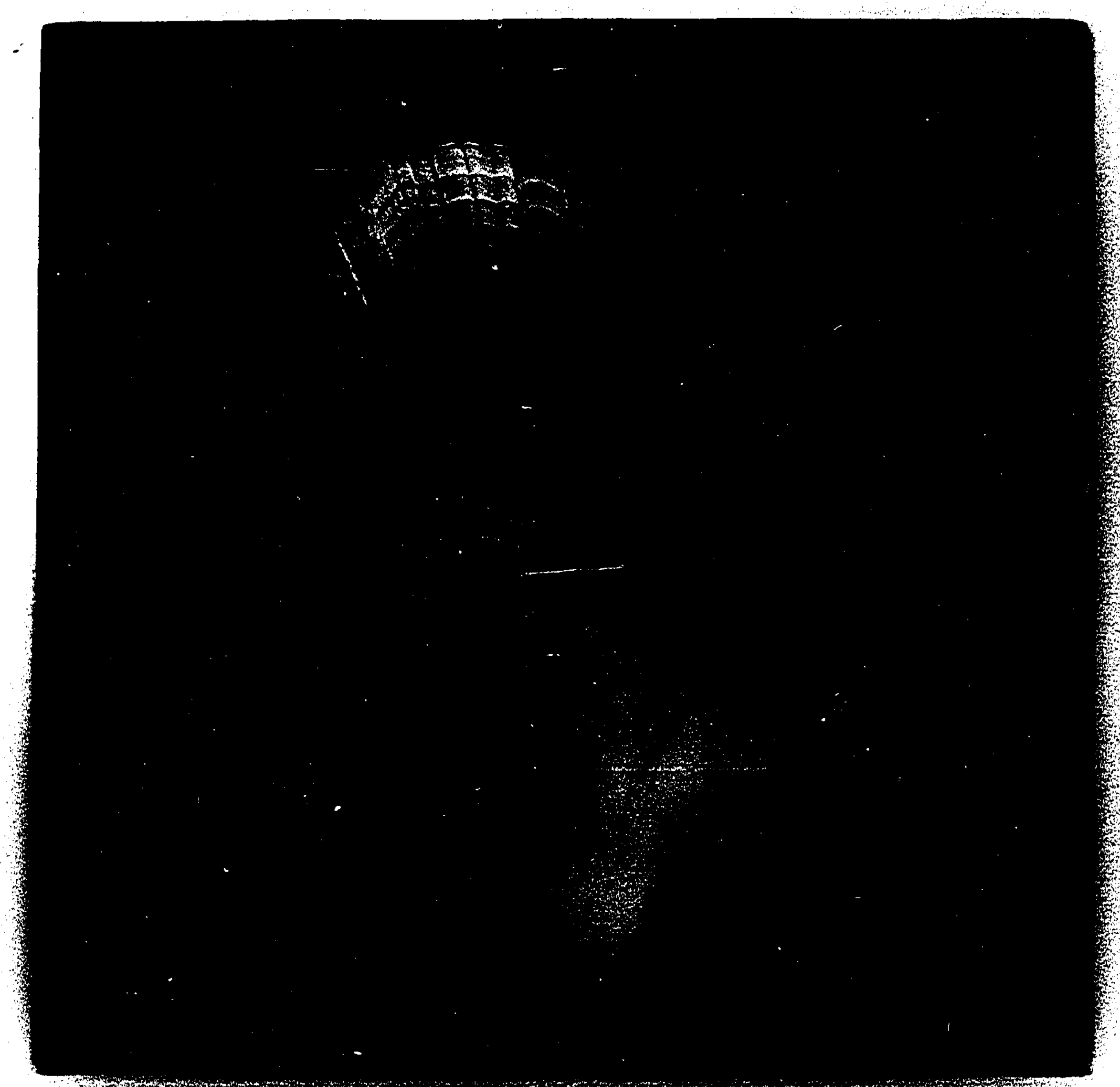

Figure 7. The opercular bone of a northern pike from Lake Kulik. This pike was 848 mm in length and aged at 14^{+}. Due to the photographic process, two annuli have been lost in the thick basal portion of the bone. A Walford plot could be used to find these annuli.

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isometrically according to the formula: fish length (mm) = 32.9 + 19.7 operculum length (mm). Mann did not indicate however, which method of back-calculation was used. Growth of the opercular bone and growth of northern pike from Lake Aleknagik is probably isometric. No correction for length of the fish when the bone was formed was deemed necessary. The apparent allometric relationship is probably a result of the absence of data for small pike in the regression and the use of total length instead of fork length.

Age-length relationships for northern pike in the Wood River Lakes system, when plotted on semi-log paper clearly gave two straight line relationships: one for northern pike ages 1^+ through 3^+ and another for ages 4^+ through 18^+. In the present study many age-length relationships are compared and tested for homogeneity of slope using an F-test (alpha = .10). These tests treat ages 1^+ through 3^+ and ages 4^+ through 18^+ separately and will be referred to in this paper as the "younger age classes" and the "older age classes" respectively.

Age-length relationships constructed from observed and back-calculated values from opercular bones of northern pike from Lake Aleknagik were compared. Significant differences occurred for the "older age classes" only.

Age-length relationships for male and female northern pike from Lake Aleknagik are not significantly different. Of 18 northern pike over 700 mm in total length from the Wood River Lakes system however, 14 were females. These limited data suggest that female northern pike in the Wood River Lakes system attain older age, and hence a larger size, than males.

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Cheney (1971) presented limited data for northern pike from the Minto Flats, Alaska, that indicate males up to age 6^+ grew slower than did females in that age group, but males grew faster than females at ages 7^+ through 9^+. Miller and Kennedy (1948) found no difference in rate of growth of male and female northern pike from Athabaska, Great Bear, and Great Slave lakes. In Athabaska and Great Slave lakes, however, female northern pike appeared to live longer, and consequently attained a larger size. Rawson (1932) also found that females lived longer than males in Waskesiu Lake. Most researchers (Priegel and Krohn, 1975; Snow and Beard, 1972; Frost and Kipling, 1965; Clark and Steinbach, 1959; Ridenhour, 1957; Munro, 1957; Carbine, 1942) found that males usually grow more slowly than do females.

Mean back-calculated lengths for age classes of northern pike from Lake Aleknagik are shown in Table 1. Since growth differences in male and female northern pike were not detected, the sexes were pooled in the analysis. Grand average back-calculated lengths and grand average annual length increments are also given in Table 1.

Figure 8 gives the age-length relationship as well as the annual length increments for northern pike from Lake Aleknagik as determined from opercular bones. The greatest increment of growth occurs during the first year of life and remains relatively rapid until about age 4^+. At this point the annual growth increment decreases to about 25 mm per year, remaining relatively constant thereafter. Northern pike ranging from 600 mm (23.6 in) to 700 mm (27.5 in) can be expected to be 11^+ to 14^+ years of age.

Figure 9 compares the age-length relationship of northern pike

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Table 1. Mean back-calculated lengths and observed lengths of northern pike from Lake Aleknagik (sexes combined).

		Average total length (mm) at end of each year of life													
Age	n	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	39	129													
2	98	173	277												
3	61	187	303	387											
4	24	194	306	398	461										
5	22	188	287	366	444	493									
6	17	160	262	333	389	445	476								
7	21	165	273	345	401	446	485	516							
8	32	173	280	355	409	447	478	507	530						
9	33	170	276	359	411	444	475	501	529	549					
10	18	170	268	351	412	446	474	499	520	542	564				
11	10	180	288	376	436	481	507	526	547	567	586	601			
12	5	155	258	338	404	455	488	516	537	558	575	596	609		
13	4	151	267	336	405	456	504	538	564	583	602	621	636	649	
14	4	163	271	356	419	464	505	539	573	594	610	631	646	663	677
	n = 388														
Range of observed lengths		125-266	192-453	290-556	382-557	368-591	429-561	484-589	458-619	474-668	484-670	561-658	580-657	582-765	583-836
Grand Average		171	283	366	419	455	482	510	534	556	581	612	635	657	677
Annual Increment of Average		171	112	83	53	36	27	28	24	22	25	31	23	22	20

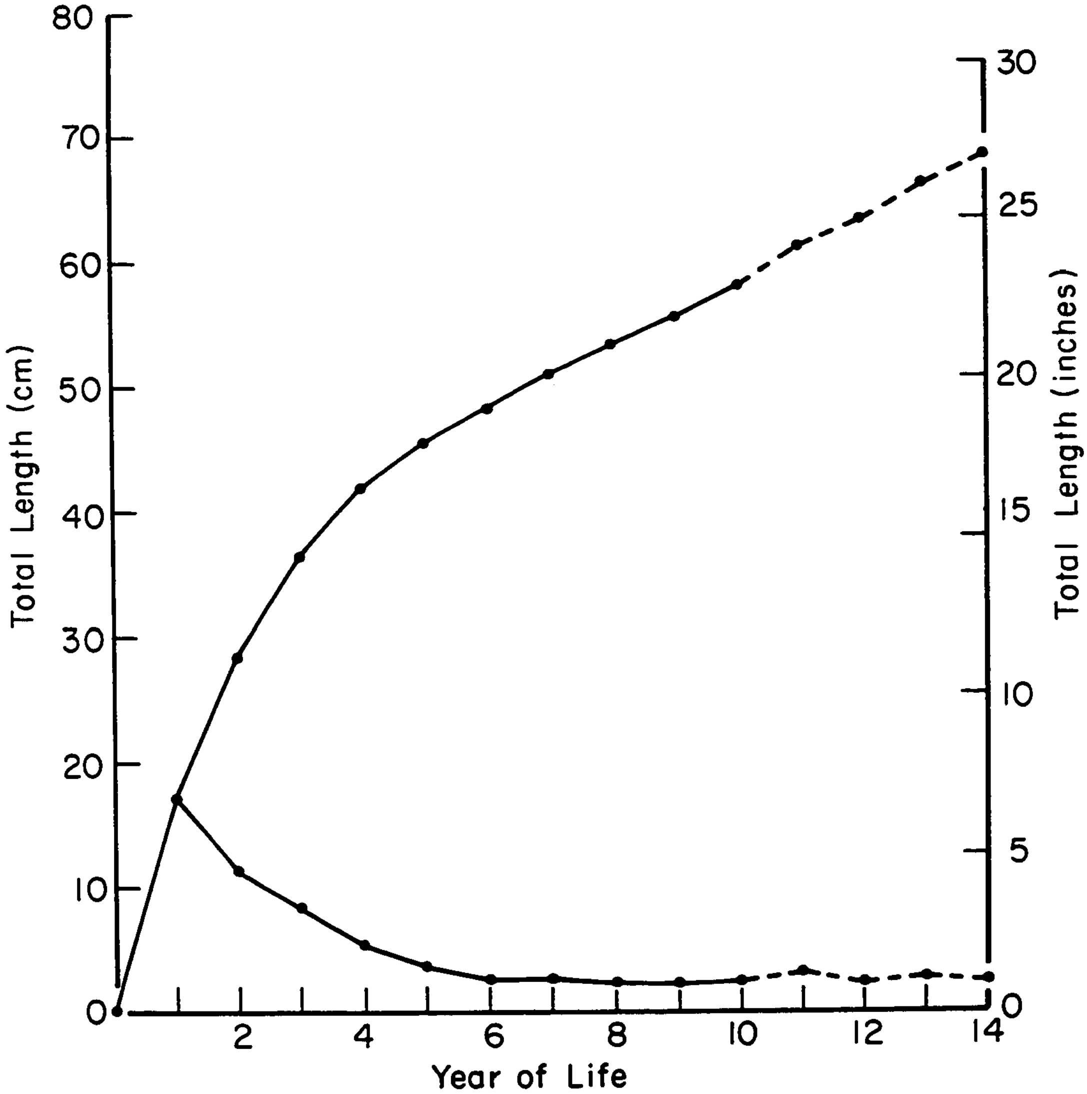

Figure 8. Age-length relationship from mean back-calculated lengths (upper line) and annual length increments (lower line) of northern pike from Lake Aleknagik.

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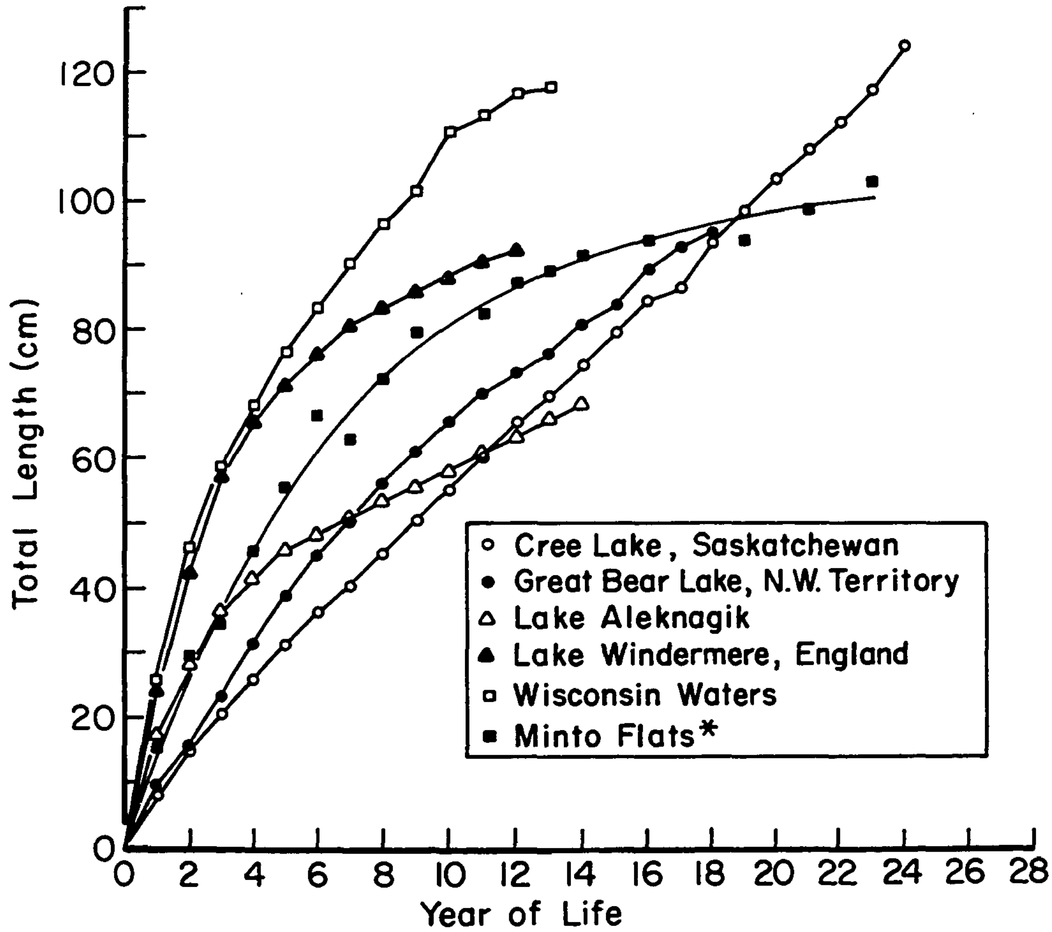

Figure 9. Comparison of growth of northern pike from various localities. *Minto Flats data are observed values in fork length. All other data are average calculated total lengths.

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from Lake Aleknagik with that of fish from Cree Lake, Saskatchewan; Great Bear Lake, N. W. Territory; Lake Windermere, England; Minto Flats, Alaska; and Wisconsin waters.

Age-length relationships were constructed for pike from Little Togiak Lake, Lake Nerka, Lake Beverley and Lake Kulik and compared with that of pike from Lake Aleknagik. The age-length relationship for Lake Nerka pike is significantly different for all age classes from that of Lake Aleknagik pike. Only the "younger age classes" of Lake Kulik are significantly different from those of Lake Aleknagik. Age-length relationships for the pike from Little Togiak Lake and Lake Beverley are not significantly different from the relationship for Lake Aleknagik pike.

Age-length relationships for pike from three distinct areas within Lake Aleknagik were compared with each other. These areas were established primarily to monitor pike movements and are further described in the chapter on movements. Area I is comprised of "tagging areas" 1, 2 and 3 (Fig. 19) and harbors the greatest densities of northern pike in Lake Aleknagik. Area II is comprised of "tagging areas" 6, 7 and 8 and represents a well defined section of pike habitat midway along the north shore of Lake Aleknagik. Pike densities are relatively high in Area II also. Area III encompasses "tagging areas" 11, 12 and 13. These three "tagging areas" contain pike habitat closest to the village of Aleknagik, where a heavy subsistence fishery for pike occurs in the spring. Comparison of age-length relationships

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for pike from Areas I, II and III showed significant differences only for the "older age classes" of Areas II and III when compared to Area I.

Otoliths were used to age 77 northern pike from Lake Aleknagik. Seventy-five percent of the otolith readings produced ages in agreement with opercular bone readings from the same fish. Seventeen percent of the otolith readings disagreed by one year and eight percent disagreed by two or more years.

Fifteen northern pike, tagged in Lake Aleknagik during the 1975 field season and representing age classes 4^+, 5^+, 6^+, 7^+, 8^+, 9^+ and 11^+, were recaptured 365 days (plus or minus three days) later. In Figure 10, mean annual growth increments of these pike are plotted against age at the time of recapture (estimated age at tagging + 1) and compared with mean annual growth increments as determined from opercular bones.

One-hundred and sixty-four northern pike, tagged in Lake Aleknagik during the 1975 field season and representing age classes 3^+ through 10^+, were recaptured at varying time intervals after tagging. Mean annual growth increments of these pike are plotted against age at the time of recapture (estimated age at tagging + 1) and compared with mean annual growth increments as determined from opercular bones (Fig. 10).

Young of the year northern pike were sampled in Lake Aleknagik throughout the latter part of the 1976 field season. Young of the year were first noticed by accident on July 9th and a 31 fish sample

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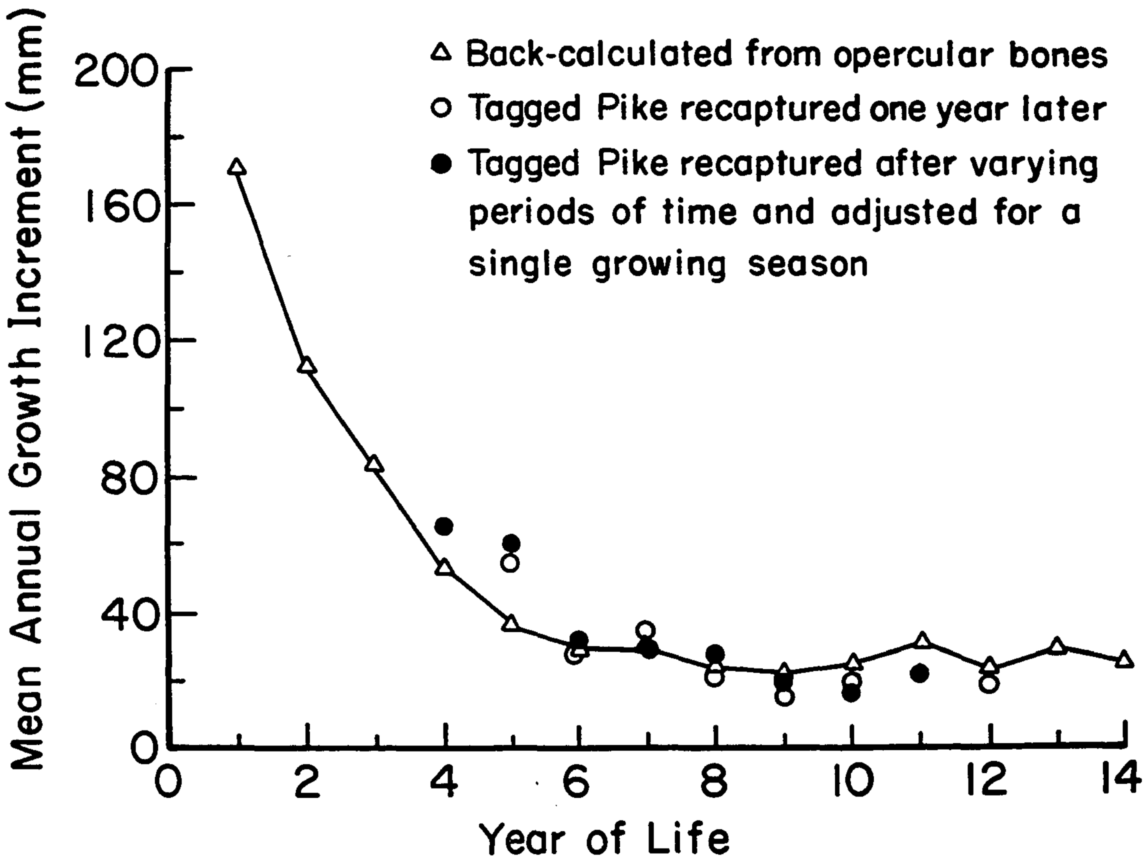

Figure 10. Mean annual growth increments of northern pike from Lake Aleknagik as determined from opercular bones, for tagged northern pike recaptured one year later and for tagged northern pike recaptured after varying periods of time and adjusted for a single growing season.

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was taken at that time. The pike ranged from 15 mm to 30 mm and averaged 21.9 mm in total length. On July 30th, nine individuals averaged 59 mm. A sample on August 20th showed the average length to be 87.9 mm and when the last sample of seven was taken on September 4th, the average was 96 mm.

Age and length at maturity as well as reproductive timing have been estimated by direct observation and spring trapnet catches on the spawning grounds primarily in tagging areas 1, 2 and 3 (Fig. 19). The peak in spawning activity occurred between June 12th and June 15th in 1976. "Ice-out" on Lake Aleknagik occurred approximately June 9th, but many of the shallow bays were open before that time.

Less than 4% of the spawning population sampled were of age 3^+; all of the age 3^+ pike were mature males. Northern pike less than age 3^+ were not captured on the spawning grounds. It appears that by age 5^+ and a length of approximately 438-469 mm, all northern pike in Lake Aleknagik are mature.

It is sometime helpful to be able to estimate the weight of a fish when only the length is known. The length-weight relationship for 385 northern pike from Lake Aleknagik taken throughout the 1976 field season is $\text{Log } W = -5.2458 + 3.0213 \text{ Log } L$ (Fig. 11). Log W is the common logarithm of the weight in grams and Log L is the common logarithm of the total length in mm. Length-weight regressions for male and female northern pike were not significantly different and therefore pooled to give this result. Growth of northern pike from Lake Aleknagik is nearly isometric with the pike becoming only slightly

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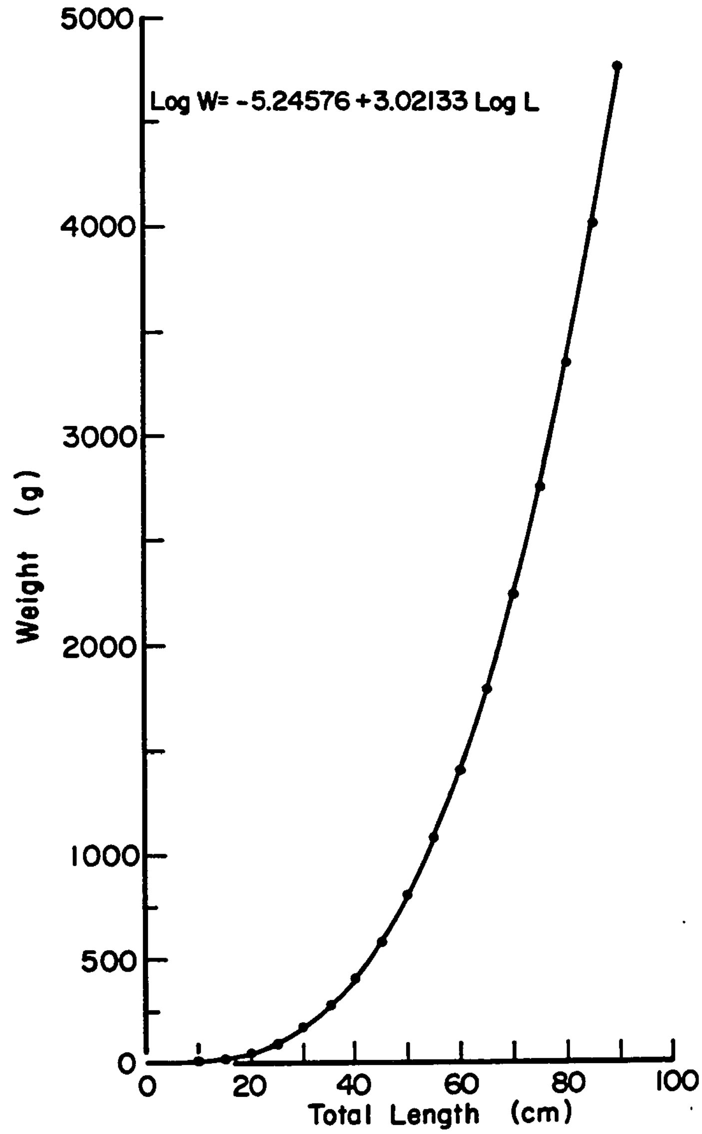

Figure 11. Length-weight relationship of northern pike from Lake Aleknagik (sexes combined).

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heavier for its length as it grows larger.

A regression of fork length on total length for northern pike from Lake Aleknagik gave the relationship: $FL = -5.458 + .9529\ TL$ ($n = 251$, $r = .9995$).

Discussion

The northern pike of Cree Lake and Great Bear Lake are slow growers but grow at a constant rate (Fig. 9). These lakes produce large pike but the pike are very old. Growth of northern pike in the Minto Flats is very good for northern latitudes and 20 pound northerns are not uncommon (K. T. Alt, Ak. Dept. of Fish and Game, personal communication). These large pike are also very old. Lake Windermere and Wisconsin northern pike grow rapidly and reach large sizes but are relatively short lived. Wisconsin northern pike at age 10^+ are almost twice as large as northern pike at age 10^+ from Lake Aleknagik. Growth of northern pike from Lake Aleknagik is perhaps above average for the first three years of life and then tapers off rapidly so that in later years growth is far below that of pike from other waters.

Over 2000 northern pike from Lake Aleknagik were caught and measured during the two field seasons of this study. Many types of gear were used and all areas of Lake Aleknagik were fished. The two largest northern pike caught were 827 mm and 836 mm long. Only 20 northern pike over 700 mm were taken. Apparently few large northern pike over 800 mm (31.5 in) and 3350 grams (7.3 lb) exist in Lake Aleknagik.

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These data and information from local residents suggested that northern pike were larger in the other lakes of the Wood River Lakes system. Not more than four days each were spent sampling northern pike in Little Togiak Lake, Lake Nerka, Lake Beverley and Lake Kulik. In most cases, sampling was confined to a very small area of each lake. Except for Lake Nerka, northern pike in these lakes were larger and those over 800 mm numerous. Lake Nerka is the largest of the Wood River Lakes and was sampled the least during this study. It is probable that large pike exist there also. Little Togiak Lake produced a northern pike that was 1045 mm in length and both Lake Beverley and Lake Kulik yielded northern pike over 900 mm. The observed differences in size of northern pike from Lake Aleknagik versus other lakes in the Wood River Lakes system prompted the sampling of Little Togiak Lake, Lake Nerka, Lake Beverley and Lake Kulik for age and growth information.

Great caution should be used when evaluating results of the age and growth studies that compare age-length relationships of pike from other lakes in the Wood River Lakes system with those from Lake Aleknagik, as well as age-length relationships for pike from three distinct areas within Lake Aleknagik with themselves. Growth in all cases was extremely variable. This is consistent with the findings of other researchers. Carbine (1945) demonstrated the tremendous growth potential of northern pike and found the variation in size of individuals at a given age to be enormous. Clark and Steinbach (1959) observed growth variations of 74 mm to 483 mm in length calculated at

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the formation of the first annulus in northern pike from East Harbor, Ohio. Bracken and Champ (1971) found length variation in Irish northern pike quite remarkable. Major length differences were observed within the same year class and in fish of the same sex. Length of age 1^+ northern pike from Lake Aleknagik as back-calculated from opercular bones varied from 71 mm to 260 mm.

Variation in growth of individuals and among entire year classes has been attributed directly and/or indirectly to population density, restricted space, competition for food, weather conditions, time and duration of spawning and water levels during the spawning season.

Sample sizes from all lakes in the system except Lake Aleknagik for age and growth comparisons were small. Samples were collected from only one or sometimes two distinct locations within each of the lakes, except Lake Aleknagik, and hence, any differences in observed growth can only reflect differences between that specific location where the sample was collected and Lake Aleknagik.

Age class representation within the samples was poor, sometimes resulting in the domination of a sample by just a few age classes. For example, 88% of the Lake Nerka sample was less than 4^+ while 81% of the Lake Beverley sample was greater than 3^+. Better representation of age classes occurred in the Little Togiak Lake and Lake Kulik samples. All age classes were well represented in the large Lake Aleknagik sample.

Since differences in growth may have occurred in various areas of Lake Aleknagik itself, one must assume that differences probably

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occur within the other lakes of the system as well. Considering the immense size of the Wood River Lakes and the diverse habitat occurring in each, growth is probably influenced by the location of the pike within the system and the character and quality of the niche occupied. With sometimes miles separating one isolated pike-inhabited bay from another, it is easy to perceive the chance for growth differences.

However, northern pike in Little Togiak Lake, Lake Beverley and Lake Kulik reach larger size than those of Lake Aleknagik. One can conclude that northern pike in these lakes are growing at a faster rate or that they are living longer which allows them to reach a larger size. If the age-length relationship for Lake Aleknagik northern pike is valid for the other lakes in the system, then the 900^{+} mm pike of Little Togiak, Beverley and Kulik lakes are approaching 25 years of age.

The significant differences in age-length relationships that occurred between Lake Nerka and Lake Aleknagik are somewhat misleading. The rate of growth of Lake Nerka northern pike for all age classes is significantly greater than Lake Aleknagik. The age-length relationship for Lake Nerka, however, is actually disjunct, with the average length at age 3^{+} greater than the average length at age 4^{+}. Consequently, the average lengths for Lake Nerka northern pike, ages 1^{+} through 3^{+}, are larger than in Lake Aleknagik, but the average lengths for Lake Nerka pike, ages 4^{+} through 18^{+}, are actually smaller than the average lengths of pike from Lake Aleknagik for those same ages.

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A possible explanation for this inconsistency is that the sample was taken from two different locations within Lake Nerka. The first sample was made up of northern pike that were primarily 1^+ to 3^+ fish. The second sample had primarily large fish that were 4^+ or older. If the growth rate was different between the two sampling locations, then the observed result would not be unexpected. This lends support to the hypothesis that growth rates vary within lakes as well as between them.

The significant differences in age-length relationships between Lake Kulik and Lake Aleknagik are more easily interpreted. The rate of growth for Lake Kulik northern pike, ages 1^+ through 3^+, is significantly higher than that of Lake Aleknagik northern pike and though not statistically significant, the rate of growth of ages 4^+ through 18^+ is also greater for Lake Kulik pike. Hence, the lengths of Lake Kulik northern pike at any given age are consistently greater than Lake Aleknagik northern pike. At age 9^+, Lake Kulik northern pike are 191 mm larger than Aleknagik pike as calculated from opercular bones.

The Lake Kulik sample is believed to be representative since there are basically only three locations where northern pike occur in the lake. Two of these locations are represented in the sample. Northern pike of Lake Kulik are believed to be the largest in the system.

The age and size of northern pike at sexual maturity varies with latitude and fertility of the waters inhabited (Toner and Lawler, 1969). Fast growing populations, generally found in southern latitudes, mature at earlier ages than those in northern latitudes where growth is

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generally slow. There is a wide variation in age at which pike mature but variation in length when maturity is reached is much less. Frost and Kipling (1967) concluded that length rather than age determines when a pike will spawn. They contrasted northern pike from Spanish waters where growth is rapid and pike mature at age 1^+ and a length of 45 cm with slow growing pike from Great Bear Lake where maturity is reached at age 5^+ and a length of 39 cm to 45 cm. The northern pike of Lake Aleknagik were estimated to mature at age 5^+ and a length of 45 cm. Ages of pike on the spawning grounds were based entirely on lengths of ripe fish and designated according to back-calculated lengths as determined from opercular bones. Consequently, northern pike maturing at approximately 45 cm may include young (age 2^+) fast growing pike and old (age 7^+) slow growing pike.

The mean annual growth increments of tagged northern pike from Lake Aleknagik agree well with the mean annual growth increments of northern pike as determined from opercular bones. However, when generating comparative data for northern pike recaptured at varying time intervals after tagging, some assumptions were made.

In order to plot growth increments of tagged fish it was necessary to estimate the age of the fish at the time of tagging based on age-length data as determined from opercular bones.

The primary growing period for northern pike in Lake Aleknagik was estimated and the concept of "primary growing days" introduced. This concept demands that there be insignificant growth during other times of the year and that growth within the primary growing period

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be constant. That is, growth in June is equally fast or slow as growth in August or September.

Regressions were used to estimate the mean annual growth increments (growth after 102 "primary growing days") for each age class of tagged northern pike. Extreme variation in growth and small sample sizes yielded "r" values indicating at best, weak relationships between "growth increment since tagging" and "primary growing days." The slope of the regression for each age class however, decreases with increasing age, indicating the expected decrease in growth rate with age. Despite the assumptions made, this logical approach to equating age and growth data has shown that the growth of tagged fish was very nearly the same as growth of non-tagged fish.

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HABITAT

Methods and Materials

Water depth was measured to the nearest 15 cm (0.5 ft) with a Ross depthfinder. Water temperatures were measured to the nearest 0.5 degrees Centigrade with a hand-held thermometer. Categorization of water color was purely subjective on the part of the author. Bottom type and presence or absence of vegetation were determined by diving observations, visual observation and dragging or sounding with an anchor. The above parameters were noted at all test gill net sites, as well as throughout Lake Aleknagik in pike habitat and non-habitat types and were used to describe pike habitat in the Wood River Lakes system.

Aquatic vascular plants were collected from many areas of Lake Aleknagik throughout the summer months of 1975 and 1976. The plants were pressed in the field and later identified by Dr. David Murray, Curator of the Herbarium at the University of Alaska.

In Lake Alaknagik, pike habitat were first mapped from a boat. The author then surveyed the lake via small aircraft, relating habitat as it was seen from the air to that already mapped by boat. In this way, an expertise at recognizing pike habitat from small aircraft was developed. All pike habitat in the Wood River Lakes system was surveyed on August 14, 1976. The survey was conducted from a Cessna 185 flying 161-185 km/hr (100-115 m.p.h.) at 183-244 meters (600-

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800 ft) above the water surface. Pike habitat was mapped on U. S. Geological Survey maps of scale 1:63,360 and all surface areas were computed using a modified acreage grid.

A single, variable-mesh, monofilament gill net was used to capture northern pike for stomach analysis, tagging and determining pike densities. The monofilament gill net was 1.8 meters deep and 38.1 meters long and composed of five panels, each a different mesh size (1.91 cm, 2.54 cm, 3.18 cm, 3.81 cm and 5.08 cm bar measure).

An index of the density of northern pike in a given area was determined by a "standard gill net drive." A standard gill net drive was as follows: the monofilament gill net detailed above was set parallel to the shoreline and adjacent to weedy areas suspected of harboring northern pike. The author and his assistant would then begin wading from the shore outward towards the net, splashing and thrashing the water, causing as much commotion as possible. Frightened by the disturbance, northern pike frantically attempted to leave the shallows for deeper water and were captured by the net (Fig. 12). Pike were immediately removed after the drive which lasted approximately one to five minutes. The drive was conducted systematically to keep the pike ahead of the drivers and cover the entire area between the net and shore.

Five variable-mesh, experimental, sinking gill nets were fished in Lake Aleknagik from June 14, 1976 to June 30, 1976 to test for the presence of northern pike in areas that did not qualify as pike habitat. Each experimental gill net was 1.8 meters deep and 38.1

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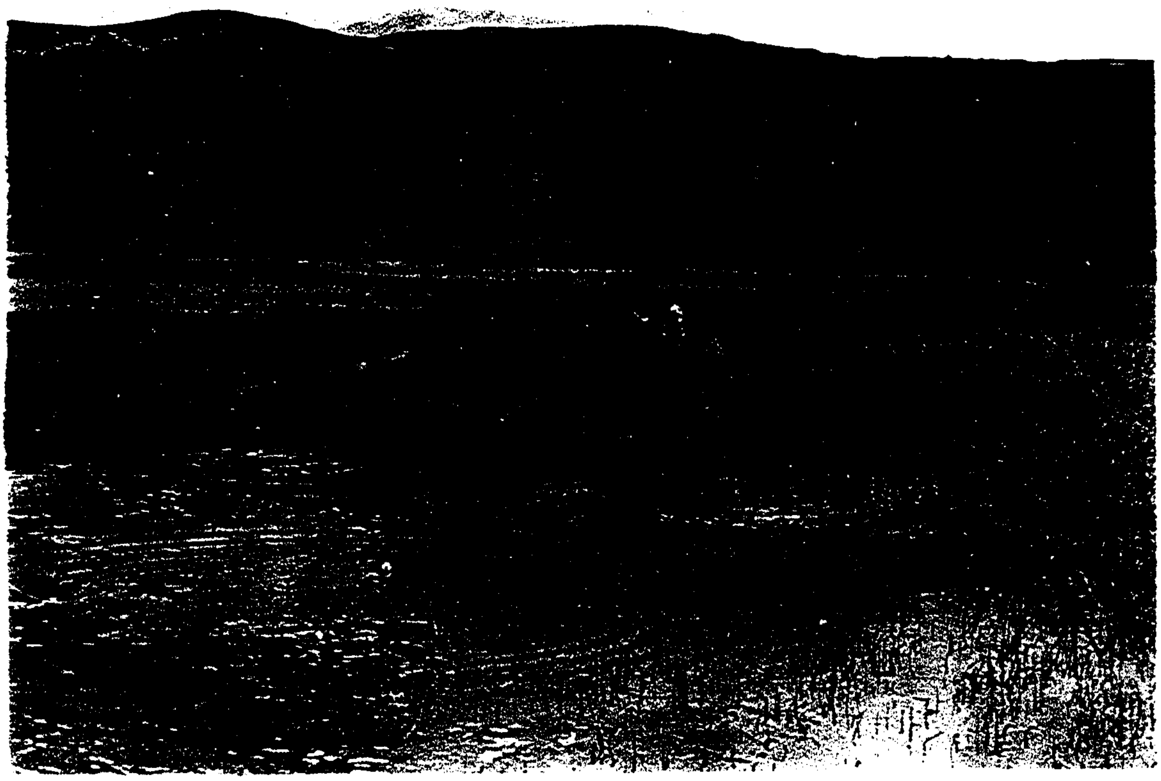

Figure 12. A "driver" frightens northern pike into a monofilament gill net set parallel to the shoreline and adjacent to weedy areas where pike are found. Notice disturbances along the gill net floats where fish are hitting the net.

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meters long, constructed with multifilament and composed of five panels, each a different mesh size (1.27 cm, 1.91 cm, 2.54 cm, 3.18 cm and 3.81 cm bar measure). A "gill net day" was defined as one experimental gill net fished in a single location for 24 hours at any given location. Twenty-five gill net days were expended throughout Lake Aleknagik in waters believed to contain no pike. An equal number of the 25 gill net days were expended at approximately fifteen meter, twelve meter, nine meter, six meter and less than three meter depths. An additional eight gill net days were expended in largely littoral areas that were either considered marginal habitat or in close proximity to known pike concentrations.

Results

Pike habitat in the Wood River system was optimal when water was brown in color, relatively warm and shallow and contained dense stands of aquatic vascular plants usually rooted in a muddy bottom. Northern pike densities were great in littoral areas where all of the above characteristics coincided. Considerable variation in pike habitat occurred throughout the system, however (Fig. 13).

During the summer months, the northern pike of Lake Aleknagik were found in waters no deeper than 5.5 meters (18 ft) with the great majority inhabiting waters less than two meters (6.5 ft).

Maximum water temperatures for pike habitat were recorded on July 8, 1976. Temperatures ranged from 24 C (75 F) at the surface to 19 C (66 F) 30.5 cm (1 ft) below the surface.

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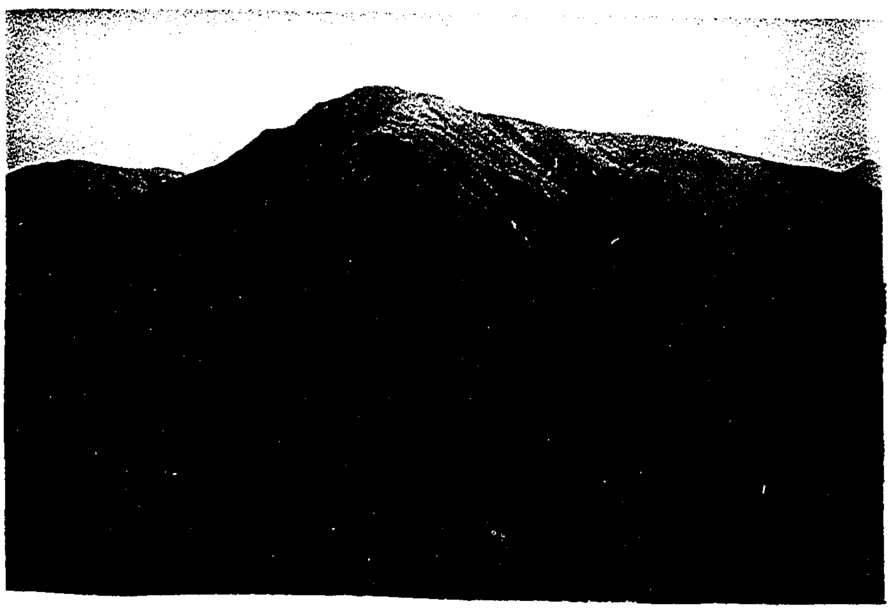

Figure 13. Northern pike summer habitat in Lake Aleknagik. Upper photograph shows a dense stand of *Equisetum* sp. in tagging area three. In tagging area eight (lower photograph), *Carex* sp. dominate the shoreline while *Equisetum* sp. and *Arctophila fulva* are scattered in deeper water (foreground). Northern pike are abundant in both areas.

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Aquatic vascular plants were the single most important characteristic of pike habitat, providing cover and sites for reproduction. Aquatic vegetation of the shallow pike-inhabited bays displayed marked zonation with respect to species and plant types. Utilization of plant species by northern pike shifted as the summer went by and floral succession progressed. This shift was related primarily to fluctuations of water level and maturation of plant species.

The sedges, Carex aquatilis, Carex lynbyaei and Carex rostrata were most heavily utilized in May and June and nearly all observations of spawning pike indicated that they were the primary spawning substrate. By July, water levels in Lake Aleknagik had dropped to such an extent that many of the sedges were no longer accessible. At this time the horsetail, Equisetum fluviatile, became the dominant plant species utilized by northern pike. In late July and August, northern pike were most abundant in the pondweed Potamogeton perfoliatus. Other plant species associated with pike habitat include the rose, Potentilla palustris, the water milfoil Hippuris vulgaris, the bur reed Sparganium hyperboreum, the grass Arctophila fulva, the crowfoot Ranunculus trichophyllus and the sedge Eleocharis palustris. Young of the year pike were abundant in the sedge Eleocharis palustris and appeared to favor it over other species in some areas.

There are 15.3 km^2 (5.9 mi^2) of pike habitat in the entire Wood River Lakes system. This is less than five percent of the total surface area of the system. There are 3.6 km^2 (1.4 mi^2) of pike habitat in Lake Aleknagik which is also less than five percent of the total

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surface area. The location of pike habitat in Lake Aleknagik, Lake Nerka and Little Togiak Lake, Lake Kulik and Grant Lake and Lake Beverley is shown in Figures 14, 15, 16 and 17 respectively.

The average density index of northern pike in pike habitat areas throughout Lake Aleknagik was 7.3 pike/gill net drive. The largest catch of 72 northern pike in a single gill net drive occurred in tagging area 13 on July 7, 1975. The highest average densities of northern pike in Lake Aleknagik were found in tagging areas one, two, three and eight.

Environmental conditions at test gill net sites were extremely variable. Temperatures ranged from 3.5° C (38.3 F) to 12° C (53.6 F). Vegetation was either absent or sparse and bottom type included rock, gravel, sand and mud. Water color was noted to be either clear, brown or glacial and silty. Test gill nets fished waters from 0 to 16.8 meters (55 ft).

Test gill nets caught eleven different species of fish. Arctic char and round whitefish were most abundant, together comprising 84% of the catch.

Fishing 25 gill net days in waters of Lake Aleknagik that did not qualify as pike habitat resulted in the capture of no northern pike. However, fishing eight additional gill net days in waters of Lake Aleknagik that were considered marginal habitat or in close proximity to known pike concentrations produced a total of 33 northern pike for an average of 4.1 pike/gill net day.

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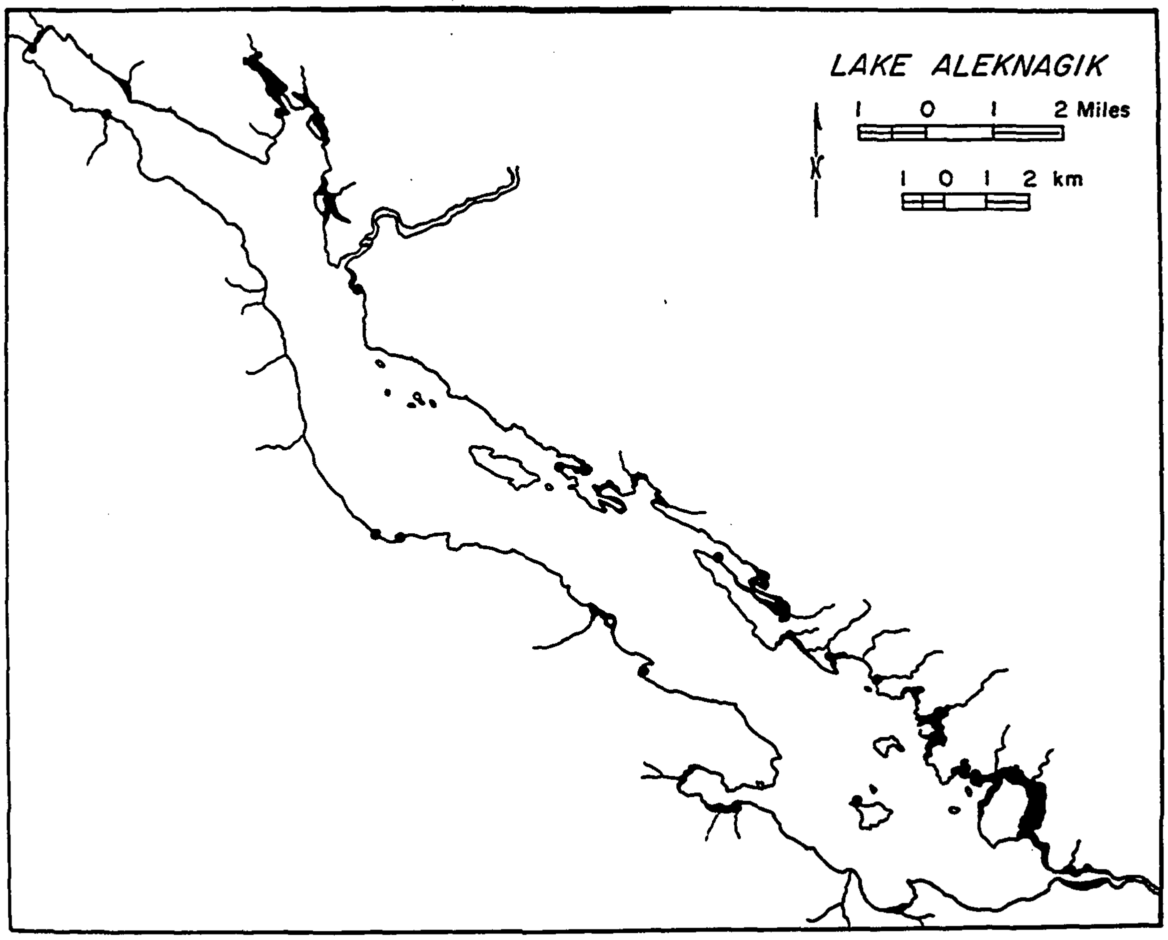

Figure 14. The location of northern pike summer habitat in Lake Aleknagik.

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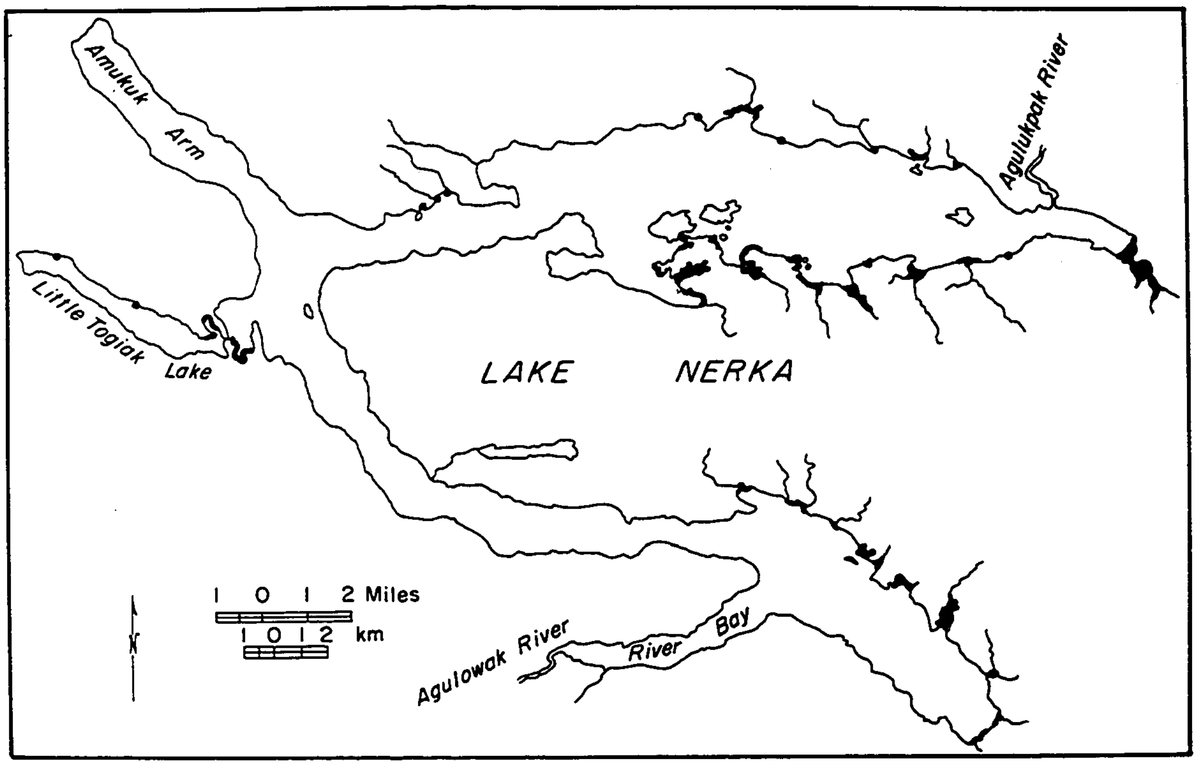

Figure 15. The location of northern pike summer habitat in Lake Nerka and Little Togiak Lake.

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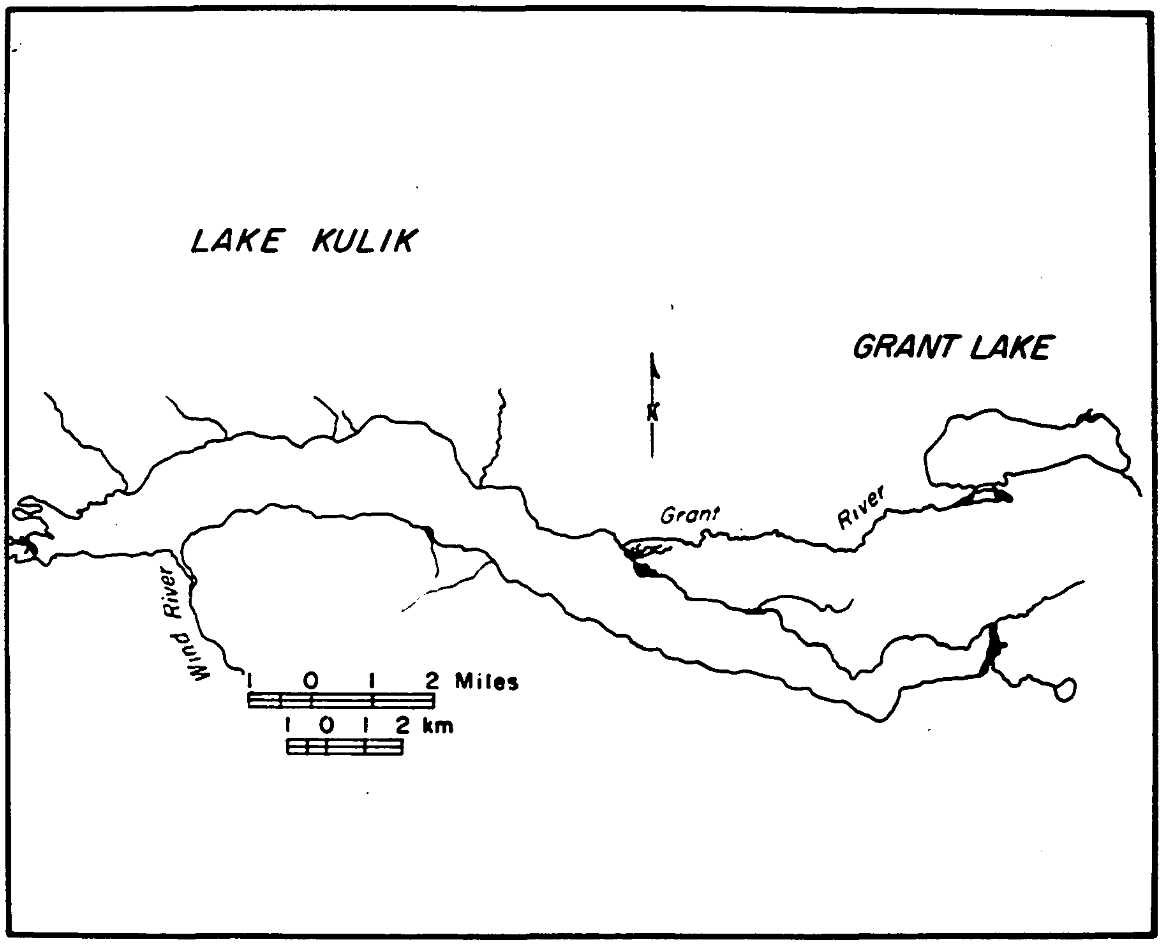

Figure 16. The location of northern pike summer habitat in Lake Kulik and Grant Lake.

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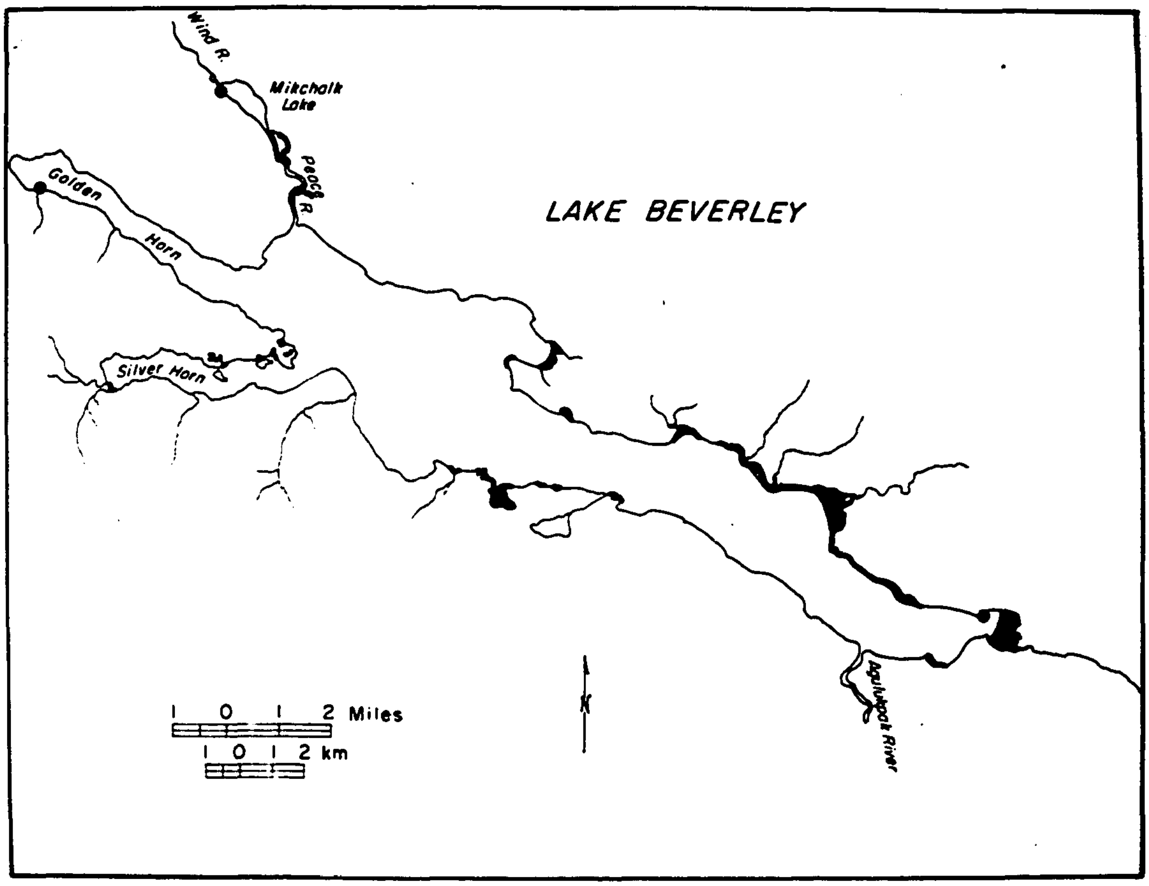

Figure 17. The location of northern pike summer habitat in Lake Beverley.

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Discussion

Northern pike summer habitat in the Wood River Lakes system is characterized by relatively warm, shallow, dark waters and abundant vegetation growing from a muddy bottom. All the above characteristics are closely linked: vegetation is found in shallow bays with muddy bottoms where water temperatures are relatively high. Diana et al. (1977) found that pike habitat during the summer in Lac Ste. Anne could be explained by similar characteristics: selection of depth, distance from shore, vegetation and bottom type. No single characteristic however, could be assigned most importance to pike selection of summer habitat. In winter, the pike of Lac Ste. Anne appeared to select habitat on the basis of depth and distance from shore.

It is the opinion of the author that the single most important component of summer habitat in the Wood River Lakes system is aquatic vegetation. With few exceptions, northern pike were always found in close association with vegetation and this was the primary criterion used to recognize pike habitat from small aircraft. Aquatic vegetation is not only essential for reproduction, but also provides cover which plays an important role in the economy of the pike (Johnson, 1960). Researchers and sport anglers alike have unquestionably stressed its importance. Carbine and Applegate (1948) concluded that the preferred spring and summer habitat of the northern pike in lake environments was the weedy bottoms of bays, estuaries and shoals. Even the Roman poet Ausonious, according to Johnson (1960), wrote: "A most hostile power to the croaking frogs, the Pike (Lucius) haunts the pools dark

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with weed and mud ..."

It has not been overlooked, however, that during the summer months the northern pike of Lake Aleknagik were found in shallow waters only. Similarily, 95% of the pike from Lac Ste. Anne were found in waters less than four meters deep (Diana et al., 1977). It is the author's opinion that if aquatic vegetation were abundant in deep waters, then the pike would inhabit those waters also.

Some exceptions to the described summer habitat of pike in the Wood River Lakes system were discovered during the course of this study. These exceptions include pike found in some areas of Little Togiak Lake, Lake Beverley and Lake Kulik. One example is northern pike found near the mouth of the Grant River. A small pod of relatively large pike is located somewhat offshore where an old river channel meets the lake proper. The water is clear and 1.5 to 4 meters deep. Water temperatures are cool relative to nearby shallow bays and vegetation is absent from a gravel bottom. The exact location of these pike is somewhat unusual. Looking at a larger area however, we find shallow weedy bays inhabited by northern pike less than 90 meters away. This unusual group of pike must certainly utilize these nearby weedy areas for spawning and perhaps habitation at some other times of the year.

Atypical northern pike habitat can also be found in Little Togiak Lake. Waters are clear and cool in numerous small bays near the outlet. The bottom drops off swiftly from the shoreline and vegetation is sparse. Narrow inconspicuous bands of Carex fringe parts of these

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bays, however. Small pike are found within the sedges while the larger pike lie just off them in deeper water. Some of the largest northern pike captured during this study were found in atypical habitat types.

Sedges, horsetail and pondweed were the dominant plant types utilized by northern pike of the Wood River Lakes system. Rawson (1932), Monten (1948, 1950) according to Priegel and Krohn (1975), Clark (1950), McCarraher (1962), Franklin and Smith (1963) and Priegel and Krohn (1975) have stressed the importance of inundated grasses and/or sedges (Carex, Eleocharis) in the role of spawning pike. The author has observed northern pike utilizing Potamogeton sp. during midsummer at Harding Lake of Interior Alaska.

The bur reed Sparganium hyperboreum and the grass Arctophila fulva were abundant and occupied large aquatic zones. These plants were not utilized by the northern pike as heavily as the sedges, horsetail and pondweed. The greatest mass of these plants lies on the surface of the water. They are light in color and grow less densely than sedges, horsetail and pondweed. It is felt that less cover was afforded by these plants, explaining the low utilization by northern pike. The rose Potentilla palustris was interspersed among Carex sp. while the water milfoil Hippuris vulgaris grew among horsetails. Both plants were scattered and seemed to play a minor role of importance to the pike. The crowfoot Ranunculus trichophyllus was found offshore and in deeper waters than all other vegetation collected in this study. Ranunculus was not heavily utilized by northern pike.

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Gill net driving was an effective means of capturing northern pike and was used as an index of pike densities. According to Miller (1952), Lawler (1950) used a similar gill net driving technique. He found that the initial drive did not take all the pike in a given area. A second attempt immediately after the first yielded about as many pike. Only the initial gill net drive in Lake Aleknagik was used as an index of pike densities, though it was clear that many pike escaped and were not captured on the first attempt. Some pike refused to leave the protection of the weed beds while others were frightened and turned away by the gill net itself. Still others seemed to become confused and disoriented by the disturbance and chose to flee in other directions.

Results of test gill netting in Lake Aleknagik for northern pike indicate that during the period June 14 to June 30, 1976 northern pike were almost entirely restricted to the few, warm, shallow weedy bays of the lake. Some test gill nets fishing in marginal pike habitat or waters in close proximity to known pike concentrations caught northern pike while others did not. The explanation for the capture of northern pike in non-habitat types is threefold: 1) a gradient must exist between concentrations of pike in summer habitat and other areas of the lake where pike are absent or densities are very low, 2) tagging studies show that a small percentage of the pike in Lake Aleknagik are wanderers and 3) test gill netting significantly overlapped the spawning period when pike are most active and likely to move about.

Test gill netting began immediately after break-up and avoided sockeye salmon returning to spawning grounds in July. The period of

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time during which gill netting took place was short, but it was felt that results obtained were representative of most of the summer period. Evidence collected in the last week of August, 1976, indicated offshore movement by northern pike in some areas. By the end of August, water levels had dropped to such an extent that some habitat areas were no longer inundated. Pike were forced to seek suitable habitat in other areas of the lake or move offshore into deeper waters. Though the former is very probable, a single gill net was used to confirm the latter.

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MOVEMENTS

Methods and Materials

One-thousand one-hundred and seventy-eight northern pike were tagged and released in Lake Aleknagik between June 15th and July 29th, 1975. Eight additional northern pike were tagged and released in Lake Aleknagik between May 26th and June 4th, 1976, by the Commercial Fisheries Division of the Alaska Department of Fish and Game.

Northern pike were tagged with Floy Tag FD-68B brown anchor tags. A five digit number on each tag identified the northern pike carrying that tag. "ADF&G WR" (Alaska Department of Fish and Game Wood River) was also printed on each tag identifying the investigators and location of the study. A "Mark II" Floy tagging gun was used to insert the T-bar anchor tag into the left side of the fish at the base of the dorsal fin passing the interneural rays (Fig. 18). The author and his assistant spent only 15 to 30 seconds to measure, tag and record the necessary information for each northern pike. The procedure was rapid and efficient, which helped to return minimally-stressed tagged fish to their environment.

A graduated-mesh monofilament gill net, a trapnet and sport angling techniques were used to capture northern pike for tagging (also for recapture). Immediately after capture, total length to the nearest millimeter, location of capture and tag number were recorded

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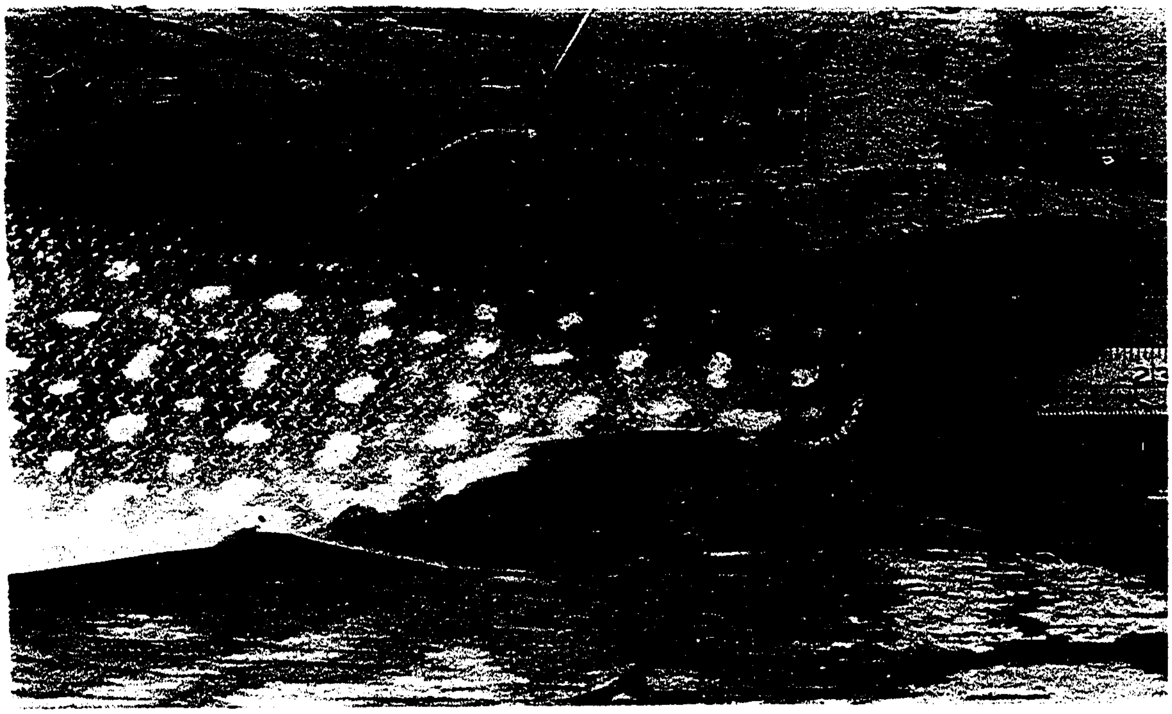

Figure 18. This northern pike was tagged with a Floy Tag FD-68B brown anchor tag. The T-bar anchor tag was inserted into the left side of the fish at the base of the dorsal fin passing the interneural rays. The inscription on the tag, "ADF&G WR 00394", identifies the fish, the investigators and the location of the study. Northern pike #00394 was tagged in area 13 and recaptured in area 11. Note the condition of the fish and tag after 341 days. Slime and algal growth have been removed from the tag.

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for each fish. When applicable, condition of the fish, sex, evidence of tag loss and other pertinent data were collected.

Lake Aleknagik was divided into 25 tagging areas to facilitate monitoring pike movements (Fig. 19). The boundaries of the tagging areas proved to be adequate since none bisected pike habitat.

To clarify the results and simplify the interpretation of the tagging data, northern pike recaptures have been divided into two separate entities. The first, "short-term movements", consists of recaptures that reflect the activity of northern pike in Lake Aleknagik over a short period of time during the summer months (June through August) of 1975 and 1976. Included are northern pike that were recaptured during the 1975 field season not long after tagging and those northern pike that were recaptured twice during the 1976 field season. The second entity, "long-term movements", reflects the activity of northern pike in Lake Aleknagik over an extended period of time, including no less than the months August, 1975 through April, 1976 and in most cases summer months of both years.

An informational poster advertising for northern pike tag returns was displayed in the Aleknagik Village Post Office during the summer months of 1976. The poster requested that sport and subsistence fishermen catching tagged northern pike send the tag or tag number, location of capture and other pertinent data to the author or Alaska Department of Fish and Game personnel stationed in Dillingham or King Salmon, Alaska. Sport angling and subsistence fishing for northern pike in the Wood River Lakes system is virtually unregulated.

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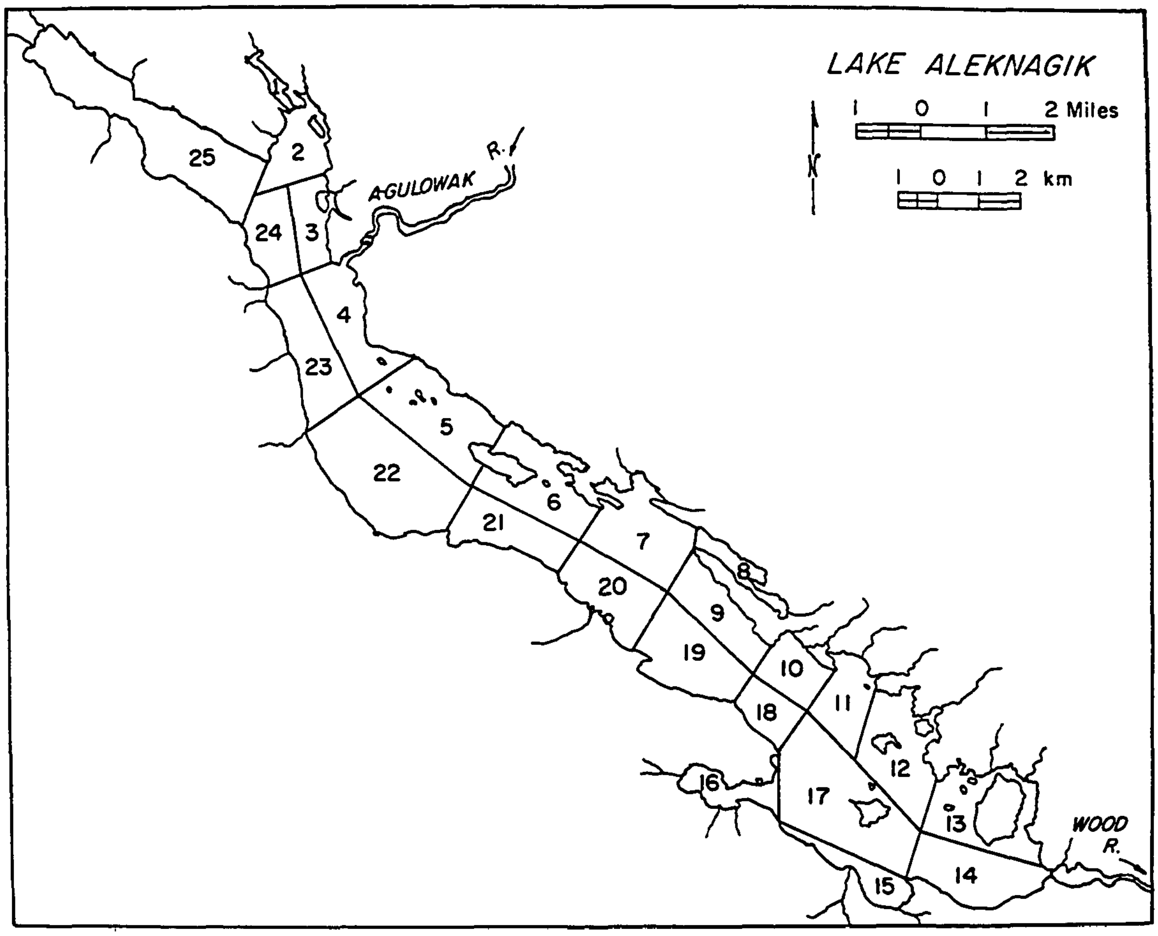

Figure 19. Lake Aleknagik was divided into 25 tagging areas to facilitate monitoring pike movements.

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Sport anglers enjoy a no closed season and no bag limit for northern pike. Subsistence fishermen are limited only by quotas designated on their Bristol Bay subsistence fishing permits.

Alaska Department of Fish and Game personnel working in the Wood River Lakes system on fisheries research and management projects were instrumental in obtaining valuable tag return data and increasing public awareness of ongoing pike research. Local sport angling lodges were kept informed of research in their area and were highly cooperative in all ways. The author and his assistant contacted, in person, local residents, fishermen and other recreational users while working in the field. All tag returns were voluntary and no rewards were offered.

Results

Two-hundred and eighty-five tagged northern pike were recaptured in Lake Aleknagik at varying time intervals after tagging for a tag return of 24%. Forty were recaptured a second time and two a third time (total recaptures = 327). Two-hundred and seventy-nine (85%) of the northern pike tag recoveries were made during pike research activities. Four (1%) were reported by Alaska Department of Fish and Game personnel working in the area, 4 (1%) tags were turned in by sport anglers fishing in the area and 40 (12%) tags were recovered by residents of Aleknagik in the subsistence fishery.

Eighty-three northern pike recaptured during the 1975 field season and 13 recaptured during the 1976 field season produced 96 total recaptures reflecting short-term movements of northern pike. The time interval from tagging to recapture or from recapture to

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recapture varied from 1 to 50 days ($\bar{x}$ = 14 days). Fifteen (16%) of these tagged pike had moved to new tagging areas while 81 (84%) were found in their original tagging location.

Of 231 tag recoveries reflecting long-term movements of northern pike, 38 (16%) had moved to new tagging areas while 193 (84%) were captured in the same location in which they had been tagged or recovered a previous time. The time interval from tagging to recapture or recapture to recapture varied from 250 to 436 days ($\bar{x}$ = 353 days).

Figure 20 shows the recapture location of 15 northern pike from Lake Aleknagik which were found to have moved to new tagging areas after a short period of time during the summer months (short-term movement). This period varied from 2 to 35 days. Eight of the 15 northern pike moved no further than into an adjacent tagging area while 7 moved greater distances. The greatest short-term movement was displayed by a northern pike that was tagged in area "1" and recaptured in area "25." This is a minimum distance of 6 miles in 35 days.

Figure 21 shows the recapture location of 37 northern pike from Lake Aleknagik found to have moved to new tagging areas after an extended period of time (long-term movement). This period varied from 250 to 431 days. Fifteen of the 37 northern pike moved no further than into an adjacent tagging area while 22 northern pike moved greater distances. One pike was tagged in area "1" and recaptured 346 days later in area "13." This is a minimum distance of 17 miles.

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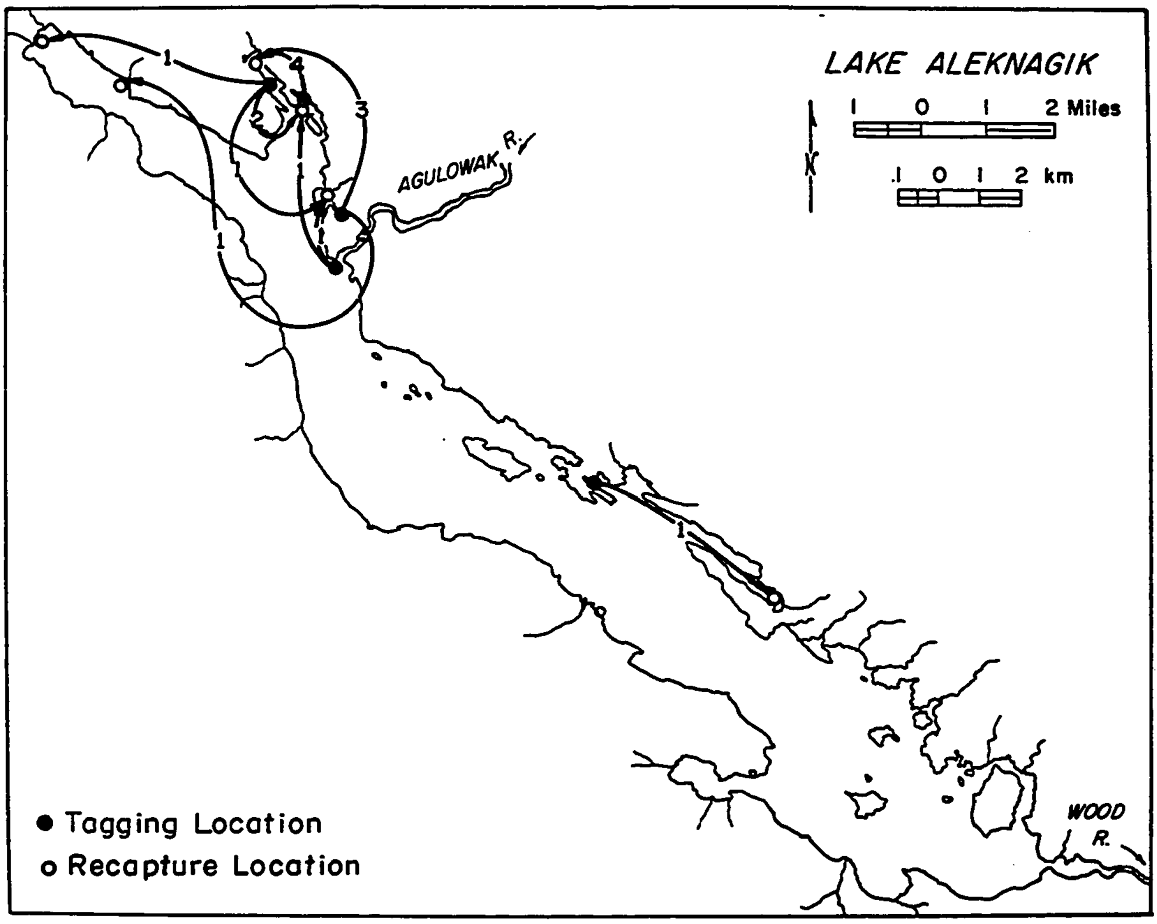

Figure 20. The recapture location of fifteen northern pike from Lake Aleknagik which were found to have moved to new tagging areas during the summer months (short-term movement). The time period from tagging to recapture varied from 2 to 35 days. The numbers included within the arrows tell how many northern pike accomplished that distance.

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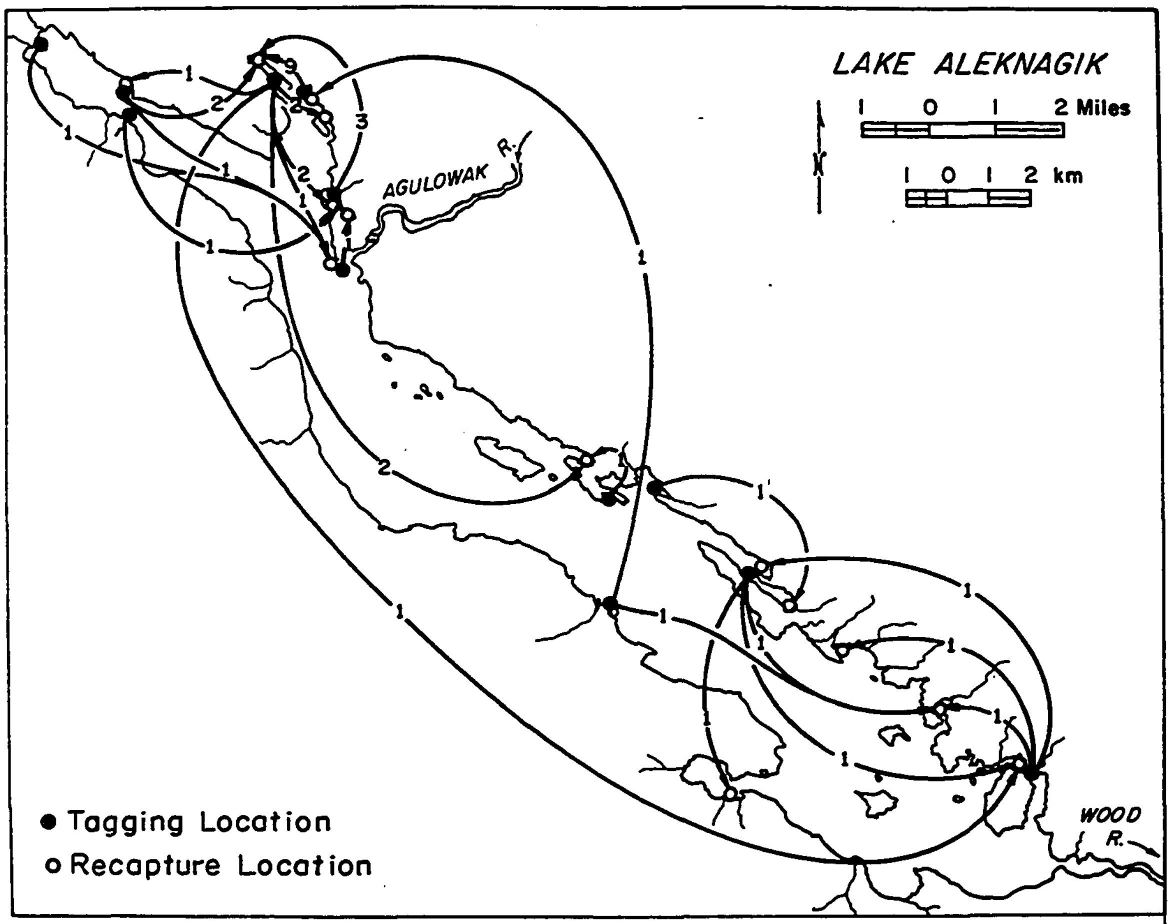

Figure 21. The recapture location of 37 northern pike from Lake Aleknagik which were found to have moved to new tagging areas after an extended period of time (long-term movement). This period varied from 250 to 431 days. The numbers included within the arrows indicate how many pike accomplished that movement.

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Of 1,283 northern pike captured and examined in Lake Aleknagik during the 1976 field season, 202 (16%) were tagged and five had clearly shed their tags. Two northern pike examined during the 1975 field season had lost their tags sometime during that summer.

Sixty-one percent of the northern pike tagged during the 1975 field season were captured with gill nets, 21% by sport angling techniques and 18% were taken in a trapnet. Tag recoveries during the 1976 field season showed that 61% of the northern pike recaptured had been originally caught by gill net, 24% taken by sport angling techniques and 15% were taken in a trapnet. These data indicate the absence of differential mortality as a result of the capture techniques (χ^2, = 0.05, nonsignificant).

<u>Discussion</u>

Fisheries biologists have utilized a variety of methods for marking northern pike for subsequent studies, including fin clips, fin punches, aluminum strap tags, monel metal strap tags, monel metal jaw tags, disc tags, dart tags, anchor tags and colored bandettes. The most widely used and accepted tagging method utilizes the strap and jaw tags attached to the maxillary, premaxillary, mandible or opercular bones. Though many fisheries biologists have used the strap and jaw tags for marking northern pike, few have evaluated their use. Shetter (1936) reviewed the jaw tag method and found it to be satisfactory for all tagging work on soft-rayed fishes. Frost and Kipling (1967) found monel metal tags attached to the upper jaw of northern pike superior to the same tag attached to the opercular bone.

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Opercular tags often damaged the opercular bone and shedding rate was high after two years. Jaw tag losses were negligible. Williams (1955) however, found that monel metal strap tags located on the mandible reduced the growth rate of northern pike by greater than 50% and the condition of the fish was so adversely affected that scale annuli failed to form. Priegel and Krohn (1975) found little evidence of tag loss among northern pike tagged with aluminum strap and monel metal jaw tags. Some tags on the lower jaw caused a definite groove to form in the jaw of larger fish. Minor irritation of the groove and surrounding tissue resulted. There appeared to be no marked retardation of growth as a result of the tag; however, the annual growth increment of untagged fish in the population was not known.

The anchor tags used in this study worked quite well. The FD-68B brown anchor tags were easily and rapidly applied under adverse weather and working conditions. Mortality caused by the anchor tags was thought to be minimal though this could not be directly measured. The tags appeared to have good retention. In 1976, only 2.4% of the tagged population were recognized to have shed their tags. This figure may be artificially high since the recapture process is often a violent one. It was noticed that some tags were shed during this time. Those pike found to have shed their tags possessed easily distinguished scar tissue around the point of insertion.

It is thought that the vulnerability of the northern pike to exploitation was not increased by the brown anchor tag. The tag appeared to have little effect on feeding and locomotion and its

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dull color should not have attracted undue predation that could result from carrying a brightly colored tag. In a four year study, Koshinsky (1972) evaluated two tag types with northern pike. He found that the barb-anchored spagetti dart tags, similar in many respects to the anchor tags used in this study, were retained longer than monofilament-attached preopercular disc tags. Growth increments of northern pike tended to be smaller for disc-tagged than dart-tagged individuals of the same sex. Disc-tagged northern pike dispersed more widely and were more vulnerable to angling. He suggested that a brightly colored tag attached to the head of a predatory species interfered with feeding, perhaps by startling prey.

Growth of tagged northern pike in Lake Aleknagik was not retarded by the anchor tags, as indicated in Figure 10. Mean annual growth increments of tagged northern pike from Lake Aleknagik agreed well with mean annual growth increments as determined from opercular bones. One disadvantage of the brown anchor tags was that they were not readily discernible upon examination. Brown in color and often coated with algal growth, the tag was difficult to spot by the casual observer when camouflaged by the green to brown dorsal surface of the northern pike. During the 1975 field season a local resident of Aleknagik, who was aware of ongoing pike research and who had been sportfishing in the area, stopped by our research facility to display his catch. When asked if he had caught any tagged pike, he confidently answered "No." He had checked each fish and was sure that none were tagged. Upon close examination of the northern pike lying in the bottom of his

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skiff, tagged fish #00005 was discovered. Had this study depended upon anglers and subsistence fishermen for tag returns, tag color would have been an important consideration. Since most recoveries were made by pike research personnel and returns from anglers and subsistence fishermen were only an added bonus, the advantages of the brown anchor tag mentioned earlier far outweighed the disadvantage of being difficult to discern by those not involved in the pike research activities.

Recaptures reflecting short-term movements of northern pike during the summer months indicate that the pike of Lake Aleknagik move very little during this time. Eighty-four percent of the recaptures were found in their original tagging locations while 16% had moved to new tagging areas. Of the 16%, more than half moved only into an adjacent tagging area. This displacement varied from only a few hundred yards up to three miles depending upon the size of the tagging areas. Recaptures reflecting short-term movement occurred before, during and after the spawning period. Some northern pike were undoubtedly recaptured enroute from winter haunts to the spawning grounds. Northern pike are extremely active during the spawning period, sometimes travelling great distances at considerable speeds. Carbine and Applegate (1948) recaptured a northern pike that had made a ten mile journey from a weir on the Muskegon River to a weir at Peterson's ditch draining into Houghton Lake in Roscommon County, Michigan. Carbine calculated that the pike, wandering through oxbows and other tributaries before finding the entrance of the ditch, travelled the 10 mile

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distance in 22 hours at a minimum average speed of 0.5 mile per hour in search of suitable spawning grounds.

Trapnet catches are an index of activity during the spawning period for northern pike from Lake Aleknagik. From June 11, 1976, when the trapnet was first installed, to June 15, 1976, trapnet catches averaged 2.7 pike per trapnet hour. From June 15th to June 30th trapnet catches dropped off to an average of 0.5 pike per trapnet hour. After June 30th the trapnet was, for all practical purposes, ineffective, though large numbers of pike were still in the area, many living in close proximity to the net itself. Since some of the tag recoveries were made before the spawning time, it is quite likely that the percent found to have moved to new tagging areas is artificially high. Some pike were undoubtedly captured on their way to the spawning grounds and may not have spawned or taken up residence at the location in which they were recaptured.

After preliminary analysis of tag return data, Alt (1970) indicated that northern pike of the Minto Flats, Alaska, displayed very little summer movement, with most of the recoveries being made in the same area. Eleven pike recaptured one year later were taken in close proximity to the tagging area. It was thought that the northern pike of the Minto Flats migrate downstream in the fall and winter in the Lower Tolovana and Tanana Rivers. This would indicate then that the pike are frequenting the same areas year after year. Cheney (1972) concluded that after spawning, the northern pike of the Minto Flats disperse and may remain in one area the entire summer. Cheney's (1971)

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data for northern pike tagged and recovered during the same summer (summers of '67, '68, '69 and '70) in the Minto Flats show that 56% were recovered within two miles of the tagging site, 13% were recovered between two and ten miles from the tagging site and 31% were recovered more than ten miles from the tagging location.

Finke (1966) tagged northern pike in the Black River near the Onalaska Spillway in La Crosse County, Wisconsin, from April 3rd to April 27th, 1964. Most of the tag recoveries were made during the summer months of that year. Of the 85 northern pike recaptured, 55% were caught in the immediate vicinity of tagging. Ninety-two percent of the recaptures were made in the Black River within five miles of the tagging site.

The northern pike studied by Cheney and Finke utilize habitat areas within river systems. The northern pike of the Wood River Lakes system however, do not utilize the clear, fast flowing rivers that connect the lakes of the system, inhabiting almost entirely only the shallow, weedy bays within the lakes themselves. It is suggested that northern pike inhabiting river system areas, in particular those systems where the rivers are slow moving and suitable pike habitat, would not only have a greater tendency to move but also to move greater distances. Carbine and Applegate (1948) found that northern pike utilizing the abundant marshes along the shores of the Muskegon River for spawning were more restless and decidedly farther ranging in their spring and summer habitats than those pike utilizing the marshes, ditches and smaller tributaries of Houghton Lake for spawning.

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Two-hundred and thirty-one tag recoveries reflecting the activity of northern pike over an extended period of time (long-term movement) indicate that the northern pike of Lake Aleknagik are homing to spawn in the spring and then become relatively sedentary in nearby summer habitat at least until August. Of the 16% of recoveries that had moved to new tagging areas, almost half had moved no further than into an adjacent tagging area, a distance varying from a few hundred yards to as much as three miles. That percentage of the recaptures found to have moved to new tagging areas may again be artificially high since some tagged pike were taken before the spawning period and may have been enroute to other spawning grounds.

It is particularily significant that most of the northern pike recaptured after a long period of time that included the winter months of 1975-76 were found in their original tagging locations the following spring and summer. In late fall or early winter, northern pike of Lake Aleknagik are forced from their summer habitat (primarily shallow weedy bays) into the lake proper, as much of the summer habitat either dries up or is reduced by ice cover. The pike then inhabit somewhat deeper waters where there is little rooted aquatic vegetation and cover is scarce. It is difficult to say how extensively the northern pike are displaced from their summer habitat during the winter months, but it is most unlikely that 84% of the 1976 recaptures found their way back to the spawning grounds and summer habitat by chance. Evidence of displacement from summer habitat into atypical habitat during the winter months comes from the recapture of several northern pike near

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the mouth of the Agulowak River in April and May of 1976, long before break-up occurred that year. Northern pike are normally absent from the mouth of the Agulowak River during the summer months.

Diana et al. (1977) studied the movements of northern pike in Lac Ste. Anne and found that the distances travelled by northern pike during the summer and winter were not significantly different. The northern pike of Lac Ste. Anne were found to utilize greater depths during the winter. The northern pike had no well defined home range and appeared to move at random throughout a relatively narrow zone around the edge of the lake.

According to Diana et al. (1977), Makowecki (1973) found very little displacement of large northern pike which had been tagged in a shallow lake and recaptured one year later. Frost and Kipling (1967) found that the northern pike of Lake Windermere become rather solitary early in life, undertaking little movement except during the spawning time. Johnson (1960) analyzed tag return data from Lake Windermere and estimated that northern pike cover an area of 0.6 to 0.7 acres per day or 0.3 to 0.4 square miles per year. He discovered that for all months of the year, excluding the spawning time, there is continuous activity at a relatively low level, but there is little disperal taking place. In April the pike of Lake Windermere become active, moving into the spawning grounds.

Malinin (1969) listed the northern pike among species which are known to have restricted movements. Malinin suggested that most fishes with restricted movements are characterized by the homing

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instinct during both reproductive and non-reproductive periods. Although not conclusive, Carbine and Applegate (1948) found northern pike from Houghton Lake returning year after year to the same area to spawn and some yearling northern pike returning to their parent spawning area in following years. Frost and Kipling (1967) indicated that the northern pike of Lake Windermere home to spawn and may home to a particular place within a spawning area. Franklin and Smith (1963) however, found no evidence of northern pike homing to a particular spawning grounds. Miller (1948) concluded that the northern pike of Square Lake, Alberta "shop around" from one spawning area to another.

Although most northern pike from Lake Aleknagik return to the same areas to spawn year after year and then become rather sedentary during the summer months following spawning, some northern pike do not home to spawn and may travel great distances even during the summer months. One pike from Lake Aleknagik travelled a minimum distance of 6 miles in 35 days before it was recaptured. Another pike was recaptured 17 miles from its original tagging location after a period of 346 days. It is difficult to say how far these pike may have wandered before reaching the recapture location. Some northern pike from Houghton Lake also travelled considerable distances (Carbine and Applegate, 1948). Five northern pike tagged at the Muskegon River weir in 1940 were recovered 11 miles downstream later that year. One northern pike tagged at the weir in 1940 was recaptured one year later, 49 miles from the point of tagging. Finke (1966) tagged

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northern pike in the Black River of Wisconsin below the Onalaska Spillway. One pike was recovered 21 miles downstream and another in the La Crosse River 20 miles away.

Although most fisheries biologists agree that northern pike have restricted movements, few have failed to record extremes. Perhaps there is a segment of every northern pike population that moves extensively, a mechanism to ensure maximum distribution of the species. Cheney (1972) made this statement about pike of the Minto Flats, Alaska: "Tag recaptures in past years (Alt, 1970; Cheney, 1971) show a few pike may move long distances during the summer but most tend to remain in the same area." Stott et al. (1963) and Funk (1957) suggested that fish populations may consist of two groups, one occupying restricted areas and the other moving extensively. Malinin (1969) wrote: "A fish population consists of mobile and sedentary components, i. e. the territorial conservatism can be regarded as a relative phenomenon." Results of tagging and movement studies of northern pike from Lake Aleknagik support the observations and ideas presented above.

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FOOD HABITS

Methods and Materials

Angling for northern pike was done throughout this study and was used as an indicator of feeding activity as well as a capture technique. Angling success or failure helped to determine when sampling would maximize the number of northern pike containing food in the foregut.

The foreguts, from the pyloric sphincter forward to the buccal cavity, were dissected from the pike as soon after capture as possible. In some cases, up to four hours elapsed before the guts could be processed.

Each stomach, including its contents, was given a number, placed in a "whirlpack", preserved in formalin and then examined the following winter. Contents of the hindgut were digested far beyond recognition and were not useful in the analysis. Frost (1954) however, examined the entire alimentary canal of pike less than 200 millimeters, as small organisms were recognizable in the intestine as well as the stomach.

With two exceptions (Rodentia, *Cottus*), vertebrates found in the pike foreguts were identified to species according to Morrow (1974) and McPhail and Lindsey (1970). All fish contents that could not be identified at least to genus were classified as "unidentified fish remains." Invertebrates were identified to class or order according

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to Pennak (1953). For graphic purposes insignificant items were classified as "miscellaneous." Invertebrates were lumped in part of the analysis.

For the purpose of foregut analysis, pike were divided into three size groups based on total length: 0 - 49 mm, 50 - 199 mm and 200 - 1,000 mm. These size groups will be referred to as "small pike", "medium pike" and "large pike."

One-hundred and fifty-two, 91 and 93 large pike were collected from Lake Aleknagik in 1976 during the months of June, July and August respectively. Thirty, 27, 25 and 31 large pike were collected from Lake Nerka, Lake Kulik, Little Togiak Lake and Lake Beverley respectively between the second and eighth of August, 1976. In July of 1975, 54 large pike were collected from Aleknagik for gut analysis. This sample was combined with the July, 1976 sample. One-hundred and seventeen medium pike were collected from the Wood River Lakes (primarily Lake Aleknagik) from July through September, 1976. Only 15 small pike were examined in the foregut analysis. These pike were taken in Lake Aleknagik on July 9, 1976 and averaged 25 mm in total length.

The numerical and volumetric methods of stomach analysis described by Windell (1971) and Rounsefell and Everhart (1953) were used for gut analysis of large pike. The numerical method gives the number of each different food item found in an individual stomach of a group of series and is expressed as a percent of the total number of items found in all the stomachs of the series. This method tends to magnify

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the importance of smaller food items. No recognition is given as to the relative size of the organism. In the volumetric method, each food item in the stomach is measured by water displacement and the food volumes for each item in a group or series are totalled and expressed as a percent of the total volume of food in the series. An occasional large bulky food item can distort the results. This method tends to mask the importance of the smaller food items.

Medium pike were analysed using the numerical and frequency of occurrence methods. The frequency of occurrence method, described by Windell (1971) and Rounsefell and Everhart (1953), expresses as a percent of the total number of stomachs examined in a series, the number of stomachs in a series in which food item occurred. This method describes what organisms are being fed upon but fails to give information as to the quantity or size of the food item.

Results

The result of foregut analysis of large pike from Lake Aleknagik is shown in Figure 22. Eighteen percent of June and July and 44% of August stomachs were empty. One-hundred and twenty-four, 119 and 52 of the stomachs for June, July and August respectively contained food. The graphic display in Figures 22 and 23 illustrates the importance of food items during each of the summer months, as well as the relative contribution for the entire summer period.

Blackfish (*Dallia pectoralis*), threespine stickleback (*Gasterosteus aculeatus*), ninespine stickleback (*Pungitius pungitius*) and sockeye salmon (*Oncorhynchus nerka*) are all important food items of northern

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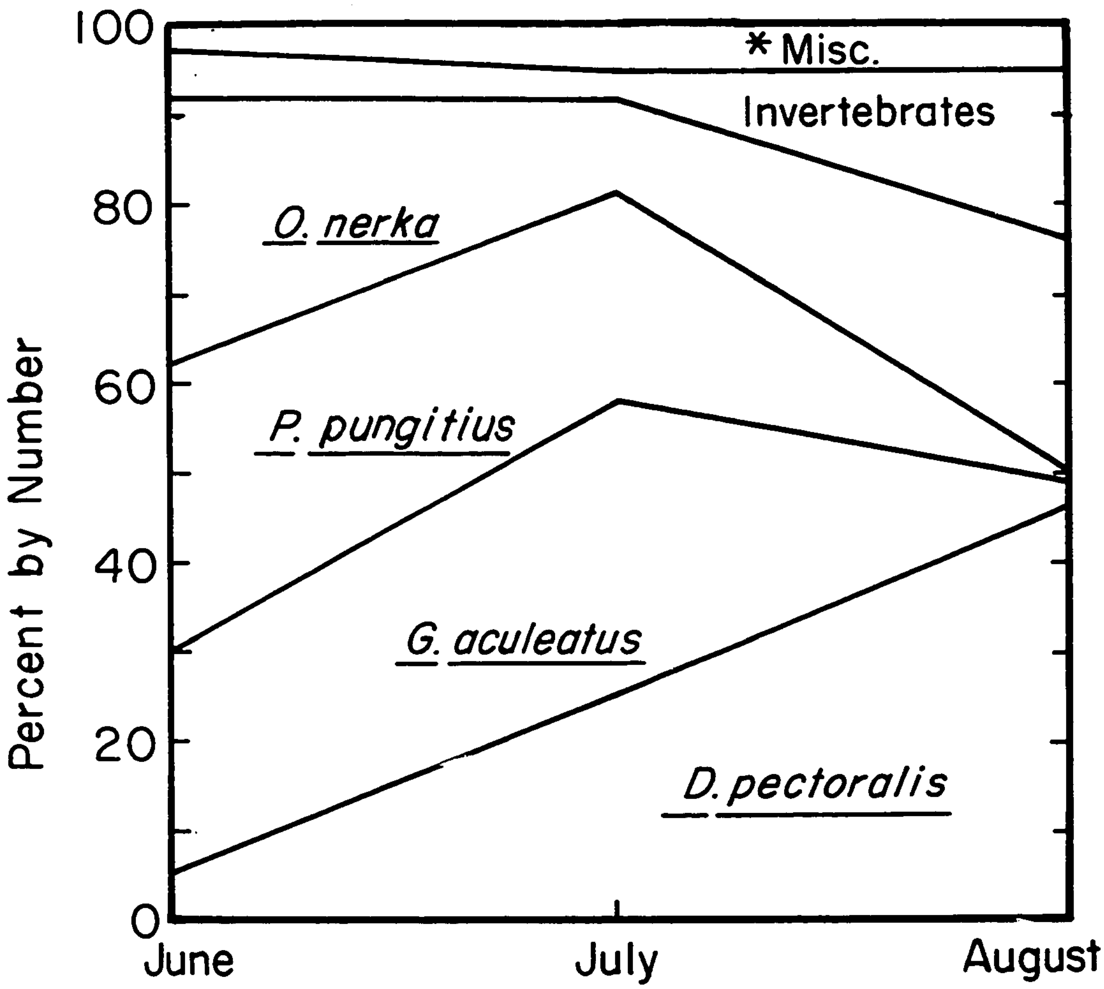

Figure 22. Foregut analysis of large pike (200 - 1,000 mm) from Lake Aleknagik. The analysis is given as cumulative percent by number for the months of June, July and August. Guts containing food are 124, 119 and 52 for June, July and August respectively. *Misc. includes Rodentia, _Cottus_, _E. lucius_, _S. alpinus_, _P. cylindraceum_, _L. japonica_ and unidentified fish remains.

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pike from Lake Aleknagik during the summer months. The importance of blackfish in the northern pike diet increased steadily from June until August, when blackfish became the most numerous food item and made up 45% of the foregut contents by number. Threespine and ninespine stickleback were important food items in June and July but became insignificant by August. Sockeye fry and fingerling remained at about the same level of importance throughout the summer. Fewer sockeye were found in the foreguts of pike in July than in the other two months, however. The classification "invertebrates" in Figure 22 is composed of the class Hirudinea (leeches), class Gastropoda (snails), order Amphipoda (scuds), order Trichoptera (caddis fly pupae), order Odonata (dragon fly nymphs) and order Ephemeroptera (mayfly nymphs). Invertebrates were most abundant in pike foreguts in August. The classification "miscellaneous" in Figure 22 includes the order Rodentia (mice), Cottus species (slimy and coastrange sculpin), Esox lucius (northern pike), Salvelinus alpinus (arctic char), Prosopium cylindraceum (round whitefish), Lampetra japonica (arctic lamprey) and unidentified fish remains. The food item Oncorhynchus nerka (sockeye salmon) was composed primarily of sockeye fry, though sockeye smolt and fingerling were also present in the pike guts examined.

Figure 23 shows foregut analysis of large pike from Lake Aleknagik given as percent by volume for the months June, July and August. By volume, blackfish are the single most important food item, increasing steadily from June until August, when nearly 50% of the volume of food consumed is blackfish. Blackfish and threespine stickleback together

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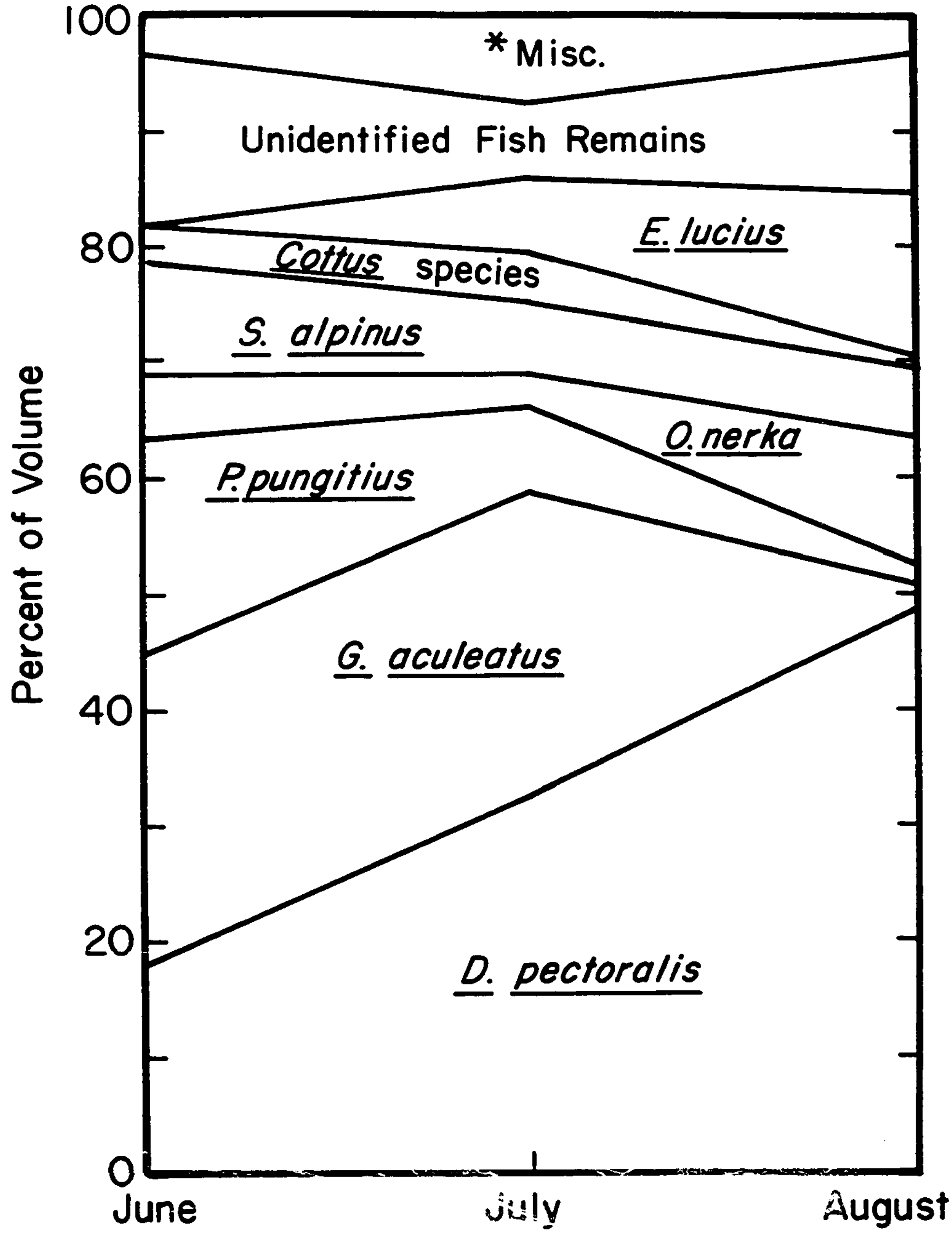

Figure 23. Foregut analysis of large pike (200 - 1,000 mm) from Lake Aleknagik. The analysis is given as cumulative percent by volume for the months of June, July and August. Guts containing food are 124, 119 and 52 for June, July and August respectively. *Misc. includes Rodentia, P. cylindraceum, L. japonica, Gastropoda, Hirudinea, Amphipoda, Trichoptera, Odonata and Ephemeroptera.

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make up over 50% of the food consumed by northern pike for the entire summer period. The role of ninespine stickleback and sockeye salmon as food items for the northern pike, when expressed as a percent of the total food volume, is much less than when expressed as a percent of the total number of food items. Together they make up about 20% of the total volume of food consumed over the entire summer period. Northern pike, sculpin and arctic char were insignificant food items numerically, but due to their relatively large size, appeared as significant items in the volumetric analysis. Northern pike as a food item was non-existent in June, but as the summer progressed, became more important. In August northern pike made up about 10% of the food volume consumed by other pike. Invertebrates were an insignificant food item volumetrically throughout the summer. "Miscellaneous" in Figure 23 includes mice, round whitefish, arctic lamprey, snails, leeches, scuds, caddis fly pupae, dragon fly nymphs and mayfly nymphs.

Figure 24 shows foregut analysis of large pike from Lake Nerka and Lake Beverley. Twenty-four and 21 of the stomachs from Lake Nerka and Lake Beverley respectively contained food. Six (20%) of the Lake Nerka specimens and ten (32%) of the stomachs from Lake Beverley were empty. Blackfish and sculpin were most heavily fed upon by northern pike from Lake Nerka while threespine stickleback and sockeye salmon were the dominant food items taken by pike from Lake Beverley. In addition, blackfish, northern pike and arctic char were significant food items fed upon by pike from Lake Beverley.

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Figure 25 illustrates the results of foregut analysis of large pike from Little Togiak Lake and Lake Kulik. Seven from Little Togiak Lake and 21 from Lake Kulik contained food. Eighteen (72%) of the stomachs examined from Little Togiak northern pike were empty while six (22%) of the stomachs from Lake Kulik were empty. Threespine stickleback, sculpin, unidentified fish remains and invertebrates were the only food categories found in the foreguts of seven northern pike from Little Togiak Lake. Threespine stickleback was the most important food item by volume and number. Threespine and ninespine stickleback were the two most important food items taken by Lake Kulik northern pike. Sockeye, arctic char, unidentified fish remains and invertebrates were also present. Arctic char made up 65% of the total volume of food eaten by the pike from Lake Kulik, but less than 5% by number.

Foregut analysis of medium pike from Wood River Lakes system, primarily Lake Aleknagik, is given in Figure 26. The total number of foreguts examined was 117, of which ten (8.5%) were empty. It is clear that young sticklebacks and mayfly nymphs are the most important foods of medium pike during the period July through September of 1976. Young stickleback were more numerous but mayfly nymphs occurred more often in the foreguts of the pike examined. "Miscellaneous" in circle (A) includes blackfish, sockeye, sculpin, leeches, dragonfly nymphs, order Coleoptera (beetle larvae) and order Diptera (Dipteran larvae). "Miscellaneous" in circle (B) includes northern pike, blackfish, sockeye salmon, sculpin, dragonfly nymphs and Dipteran larvae.

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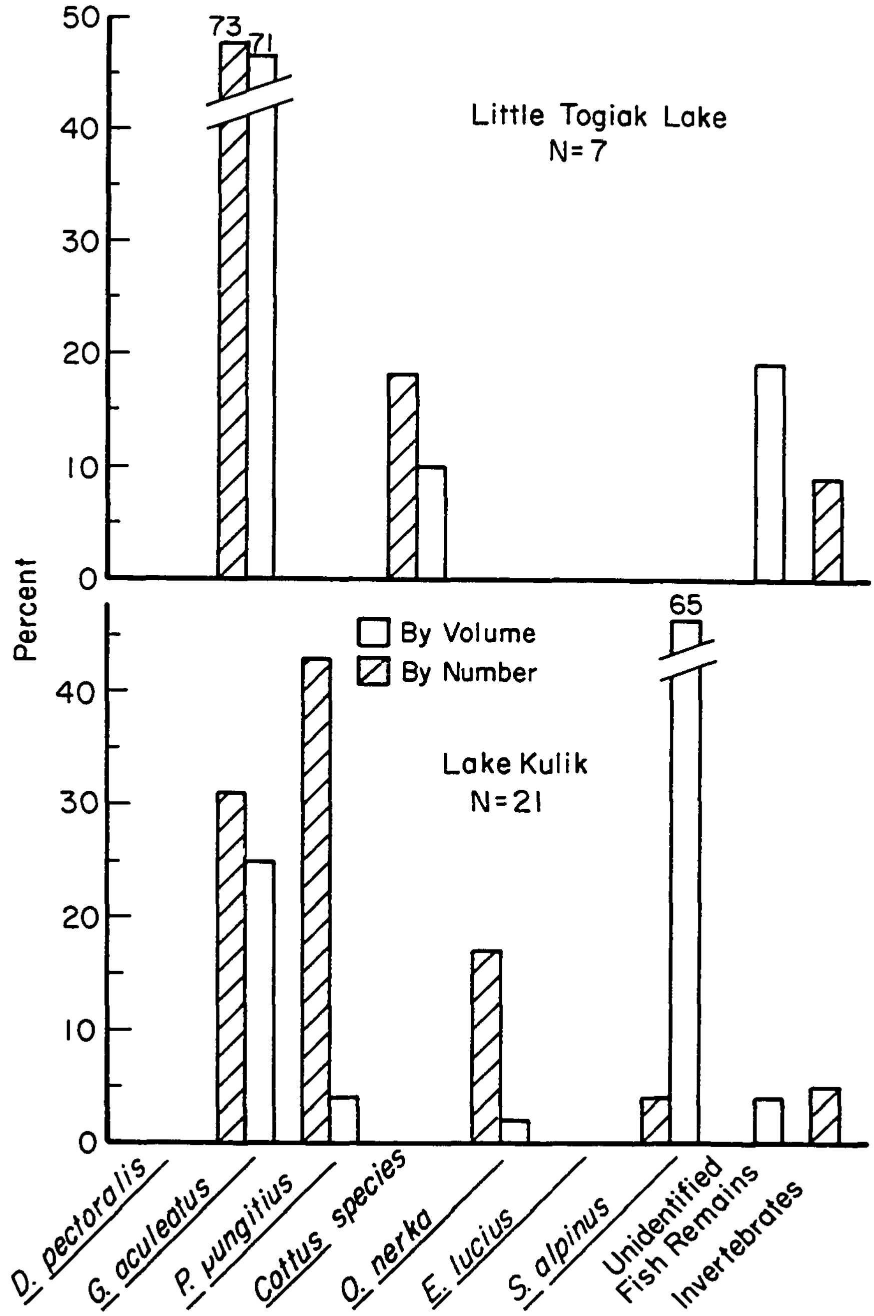

Figure 25. Foregut analysis of large pike (200 - 1,000 mm) from Little Togiak Lake and Lake Kulik. The numbers of guts containing food are 7 and 21 respectively.

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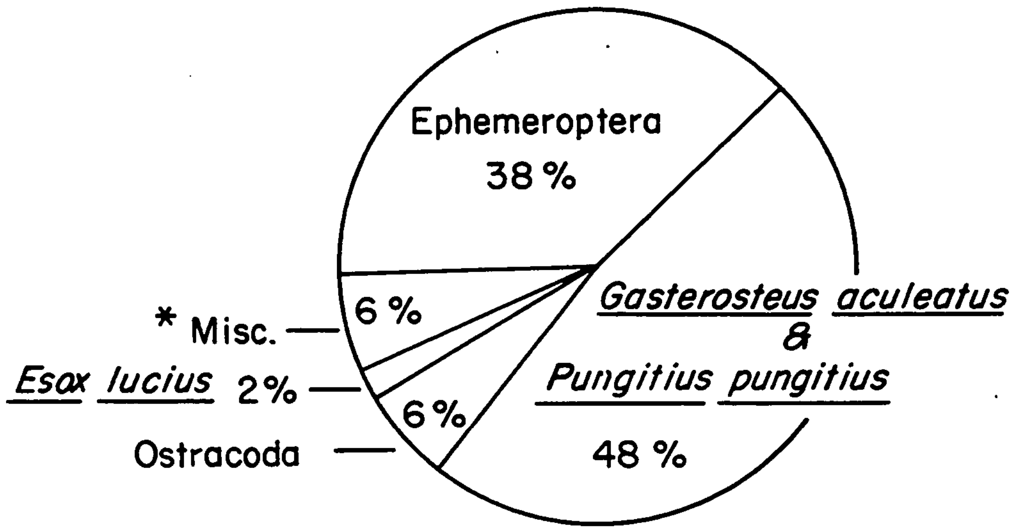
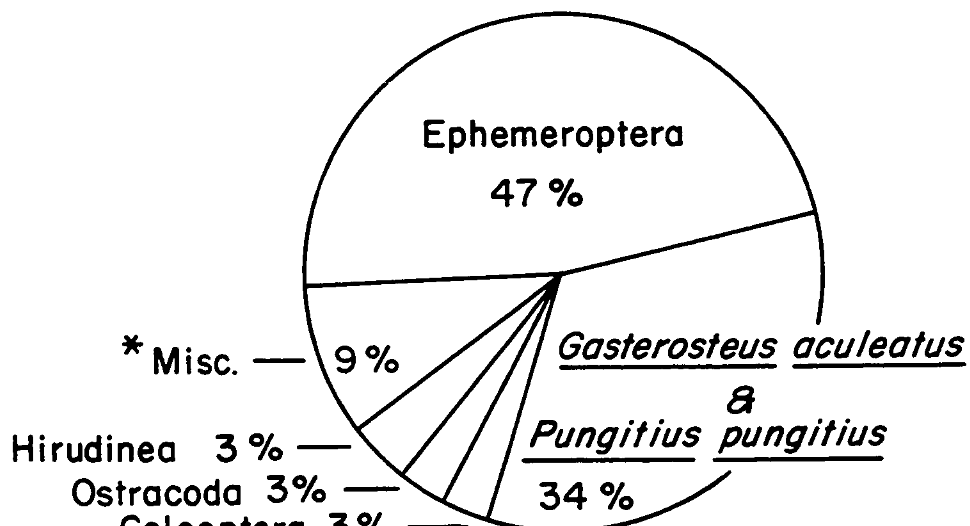


(A)



(B)

Figure 26. Foregut analysis of medium pike (50 - 199 mm) from the Wood River Lakes system. Circle (A) represents numerical analysis expressed as a percent and circle (B) represents the frequency of occurrence expressed as a percent. Guts containing food are 107. *Misc. circle (A) includes Cottus species, O. nerka, D. pectoralis, Diptera, Coleoptera, Hirudinea and Odonata. *Misc. circle (B) includes Cottus species, O. nerka, D. pectoralis, E. lucius, Diptera and Odonata.

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The foreguts of 15 small pike were examined. Four of the guts were empty. The analysis showed that similar food items were eaten by small pike as were eaten by medium pike. The most numerous food items found in the eleven foreguts examined however, were subclass Ostracoda (seed shrimps) and Dipteran larvae. Unidentified fish remains and mayfly nymphs were also found in the guts.

Discussion

The northern pike is a voracious, opportunistic carnivore that feeds the year round almost exclusively during the daylight hours. Frost (1954) and Lawler (1965) found that seasonal abundance and availability, rather than selection, appeared to be the factor most responsible for the type of food eaten. Pike are known to feed on any living vertebrate or invertebrate available to them within the size range that they can engulf.

Young northern pike may begin feeding before the entire yolk sac is absorbed, at about 10 to 12 millimeters (Hunt and Carbine, 1951; Frost, 1954). After the yolk sac is absorbed, young pike feed primarily on large zooplankton and immature aquatic insects. Frost (1954) found in Lake Windermere that young pike, 10.5 to 17.5 millimeters in total length, fed entirely on Entomostraca (small fresh-water Crustacea) while those of 35 to 200 millimeters fed primarily on *Perca fluviatilis* (perch) fry and to some extent on aquatic insect larvae. Franklin and Smith (1963) recognized a micro-crustacean food complex and an insect food complex for alevin and juvenile northern pike from Lake George, Minnesota. Insects became

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important in the diet after the small pike reached a length of 20 millimeters. Hunt and Carbine (1951) defined three feeding stages of young northern pike from the Peterson's Ditches of Houghton Lake, Michigan. During the first stage, from the time young pike begin to feed until they reach a length of about 25 millimeters, Entomostraca are the principal foods. During the second stage, when the young pike are about 26 to 50 millimeters, the food is primarily immature aquatic insects. After 50 millimeters the diet of the pike is almost entirely fish and other vertebrates. In general, the feeding sequence as the young pike grow in size is: Entomostraca to insects to fish.

The food of the adult pike is primarily fish but may include other vertebrates such as frogs, mice, muskrats and ducklings. Solman (1945) estimated that northern pike may be responsible for the destruction of 1,500,000 young waterfowl per year on the Saskatchewan and Athabaska River deltas, but Lagler (1956) found waterfowl present in only three of 1,218 pike, 14 inches long or longer, collected during the 90-day waterfowl brooding season on the Seney National Wildlife Refuge, Michigan. Fish and crayfish were the most important and consistently eaten foods of the northern pike in the refuge despite large numbers of waterfowl.

Foregut analysis of large pike from Lake Aleknagik utilized relatively large sample sizes (n = 152, 145 and 93). The samples were collected from many areas within Lake Aleknagik and over the entire summer period from June through August. This analysis adequately represents the diet of northern pike from Lake Aleknagik for this time

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period. Large pike from Little Togiak Lake, Lake Nerka, Lake Beverley and Lake Kulik however, were collected for gut analysis over a very short time period in August. These samples were not large and collected from very small specific locations within each of the lakes relative to their immense size and diversity. It is unlikely that these analyses are representative of the pike populations in those lakes. It is important however, that these pike were found to feed on the same food items as the pike from Lake Aleknagik.

Blackfish were the single most important food item taken by large pike from Lake Aleknagik during the summer months of 1975 and 1976. Threespine stickleback were a close second in importance. Moriarity (Arctic char in the Wood River Lakes, preliminary draft, 1976; Fisheries Research Institute, University of Washington, unpublished) presented limited stomach analysis data for northern pike in the Wood River Lakes sampled in July and August of 1961. These data show that northern pike from Little Togiak Lake and Lake Nerka ate blackfish. Blackfish were a part of the diet of northern pike from the Minto Flats and C. O. D. Lake, Alaska (Alt, 1968; Cheney, 1971 and 1972).

The blackfish was also one of the most important foods of the arctic char in Lake Aleknagik (Nelson 1966). Nelson studied the availability of food items to char in relation to their occurrence in char stomachs by sampling with beach-seine and otter trawl as well as variable-mesh gill nets used to capture char. He found that, with the exception of blackfish, char usually fed on the most available food.

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Because of the high ratio of blackfish in the char stomachs to blackfish in the lake fauna, Nelson hypothesized that the blackfish might be a preferred food item of the char. Nelson noted that blackfish are large sized relative to other small resident fishes fed upon by char, lack anatomical features such as spines or plates that might reduce the palatability of other food types (stickleback) and possess a high ratio of flesh to fins and other external bony structures. Evidence collected during this study suggests that blackfish were a preferred food item of northern pike also.

Minnow traps were fished throughout the pike-inhabited bays during the summer of 1976. In addition, many hours were spent wading through the shallow bays with fine meshed dipnets in search of small pike, and snorkling observations were numerous. One small blackfish was captured in a minnow trap but no other evidence of blackfish could be found. The author and Blackett (1962) have used minnow traps to capture blackfish with great success in Interior Alaska. Threespine and ninespine stickleback, sculpin and northern pike were captured in the minnow traps fished in Lake Aleknagik. The low abundance of blackfish indexed by aforementioned sampling techniques relative to high numbers found in char and pike stomachs, however, would suggest selection for blackfish by these two predatory species.

Threespine stickleback were the second most important food item eaten by large pike from Lake Aleknagik during the summer months of 1975 and 1976. Threespine stickleback were nearly as abundant in pike foreguts as blackfish, but contributed much less to the total

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volume of food consumed. Moriarity (Arctic char in the Wood River Lakes, preliminary draft, 1976; Fisheries Research Institute, University of Washington, unpublished) presented data which show that threespine stickleback were eaten by northern pike from Little Togiak Lake and Lake Nerka in July of 1961. Nelson (1966) found that threespine stickleback were the single most frequently occurring food item in the stomachs of char from Lake Aleknagik.

Threespine stickleback and ninespine stickleback were both abundant in large pike foreguts in June and July, but by August, made up only four percent by number and volume of the food eaten. The frequency of occurrence of threespine stickleback in arctic char stomachs generally increased throughout the period June 22nd through September 17th (Nelson, 1966). This inverse relationship between threespine stickleback found in pike stomachs and threespine stickleback found in arctic char stomachs during the summer period is not surprising.

Threespine stickleback are found in the littoral zone of the Wood River Lakes in early summer (Burgner, 1962). As the summer progresses they begin to move offshore and by mid August and September are almost entirely limnetic in their distribution. This may account for the abundance of threespine stickleback in the foreguts of large pike from Lake Aleknagik during June and July as well as their absence in August. Northern pike inhabit primarily the shallow weedy bays of Lake Aleknagik. As the threespine stickleback moves offshore in mid to late summer, the northern pike is left behind and the threespine

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stickleback becomes available to the arctic char, which is primarily limnetic in distribution.

Sockeye salmon were the fourth most important food item in the diet of large pike from Lake Aleknagik during the summer months. The sockeye consumed by northern pike were primarily fry and small in size. Sockeye were almost as numerous in pike foreguts as blackfish and sticklebacks, but their contribution to the total volume of food consumed was small. Despite the less significant role of the sockeye as a food item of the northern pike, its role as a second intermediate host of the parasitic tapeworm Triaenophorus crassus is of immediate importance.

Northern pike as a food item were eaten by large pike from Lake Aleknagik, Lake Nerka and Lake Beverley and by medium pike from the Wood River Lakes. Northern pike were most important as a food item for large pike from Lake Aleknagik in the month of August, when they made up approximately 14% of the diet by volume.

Cannibalism among northern pike has been reported by a number of other researchers including Frost (1954), Munro (1957), Spanovskaya (1963), Lawler (1965), Sumari and Westman (1969) and Banks (1970). Food habit studies by Alt (1968) and Cheney (1971 and 1972) showed northern pike from the Minto Flats to be highly cannibalistic during summer, fall and early winter. Hunt and Carbine (1951) found that 13.3% of the 354 northern pike less than 152 millimeters in length examined had eaten other pike. The smallest pike found to be a cannibal was 21 millimeters long.

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Invertebrates were eaten by the entire size range of northern pike from the Wood River Lakes system. They were in general only occasionally eaten by large pike but were a major part of the diet of medium and small pike. These findings are consistent with the findings of other researchers except Munro (1957) who found that the pike of Loch Choin, Scotland, fed primarily on invertebrates until reaching a length of about 500 millimeters. This was found to be due to an almost complete absence of forage fishes in the loch.

Ephemeroptera (mayfly nymphs) were eaten by small, medium and large pike from the Wood River Lakes system. Numerically, mayfly nymphs made up 38% of the diet and occurred in 47% of the foreguts of medium pike. Cheney (1971), Frost (1954), Hunt and Carbine (1951) and Franklin and Smith (1963) found that northern pike from Alaska, England, Michigan and Minnesota fed upon mayfly nymphs. Allen (1939) found that the only invertebrate food taken by the northern pike of Lake Windermere, to any great extent, was the nymphs of *Ephemera danica*. Lawler (1965) found mayfly nymphs and larvae to be the single most important invertebrate consumed by 29,477 northern pike examined from Heming Lake, Manitoba.

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EXTERNAL SEX DETERMINATION

Methods and Materials

Three-hundred and eleven northern pike from Lake Aleknagik were used to test the method of external sex determination of northern pike described by Casselman (1974). This method utilizes the external appearance of the urogenital region. Internal examination of the gonads verified the results.

Results

The 311 northern pike examined from June 21, 1976 to August 23, 1976 ranged in total length from 233 mm to 848 mm. Two-hundred and sixty-six (85.5%) were identified correctly. Accuracy of the identification improved greatly over time. No correlation between the size of the fish sexed and accuracy could be detected.

Discussion

A technique which can be used to determine the sex of a fish without conducting an autopsy or inflicting damage to it can be very useful. Prior to Casselman's work (1974), the passage of reproductive products from the urogenital opening was the only practical and reliable method of determining sex in the northern pike. This technique however, is restricted to just before and after the spawning period. Casselman examined 5,199 northern pike from 1961 to 1969. The pike ranged in total length from 200 mm to 1040 mm and were collected from two areas

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in Ontario. The urogenital technique was used to correctly sex 91% of the males and 94% of the females. The technique was reliable the year-round with varying degree of accuracy from month to month. The urogenital technique was tested on northern pike from Lake Aleknagik and was found to be relatively accurate there also. The author had little training or experience before going into the field other than reviewing the literature. Accuracy improved over time and was as high as 95.5% in one sample of 21 pike examined August 21, 1976. After an expertise had been developed, it was not difficult to determine the sex of northern pike using the urogenital technique with better than 90% accuracy.

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MANAGEMENT

Control of northern pike in the Wood River Lakes system, as a means of reducing the incidence of the parasite *Triaenophorus crassus* in sockeye salmon, does not appear to be feasible at this time. Although northern pike are limited to the few warm shallow bays (less than five percent of the total surface area) of the Wood River Lakes system, the logistics would seem to prohibit such a control program. Past efforts to control pike numbers have been largely ineffective. After ten years of intensive gill-netting in Lake Windermere, England, northern pike biomass was cut by only 47%, resulting in a 25% reduction in consumption of prey species, mainly perch. Experiments at Heming Lake, Manitoba, showed that significant reduction in numbers of northern pike by netting was practically impossible (Miller, 1952). In seven years of fishing, about two pounds of pike per acre were removed annually, resulting in an initial decrease in whitefish infection by *T. crassus*, but after the initial decrease, there was no change. Pike control at Square Lake, Alberta, probably caused a 39% reduction in the number of cysts of *T. crassus* found in ciscoes (*L. tullibee*). It was concluded that reduction of northern pike by poisoning was futile. There was no indication that given limitless money, pike could be reduced to the point where infection of ciscoes could be eliminated. A small northern pike population can keep a large *T. crassus* population in existence (Miller, 1952).

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In addition to the evidence which suggests that control of northern pike is not feasible, recent research has shown that _T. crassus_ may not be as detrimental to sockeye salmon as previously thought and probably has not caused the long term decline of red salmon stocks in the Wood River Lakes system (Burke, 1978).

As a predator of sockeye salmon (fry, fingerling or smolt), the northern pike is not important enough to warrant control. Northern pike are few, relative to other predatory species in the system, inhabit relatively limited space at least during the summer months and do not concentrate in areas where large numbers of sockeye are found. Drastically reducing pike numbers could upset predator-prey relationships that may ultimately affect the sockeye in an adverse way. The northern pike is an important predator of threespine stickleback which compete directly with sockeye fry and fingerling for food. According to Buss (1961), a fifteen year predator control program in Heming Lake, Manitoba, designed to reduce the number of pike as a means of controlling _T. crassus_ in commercially important whitefish, resulted in a striking increase in numbers of sucker, perch and burbot and a drastic decline in walleye and whitefish.

The northern pike is a major target of a subsistence fishery, primarily in the spring, by residents of Aleknagik. It was estimated that less than 500 northern pike were taken in this fishery in 1976. Considerably larger numbers may have been taken in the past depending upon the general welfare of the people of Aleknagik in any given year. This fishery occurs on Lake Aleknagik, while pike populations of other

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lakes in the system are relatively unexploited. Recent subsistence pressures on northern pike have certainly not diminished their numbers to any great extent. Subsistence use will probably continue at a low level or may decline as life styles change in Aleknagik.

The Wood River Lakes system, now part of the proposed Wood-Tikchik State Park, is rich in recreational angling opportunities. Approximately 3,000 man/days of sport angling effort was expended in the system between June 14th and September 6th, 1976 (A resumé of the creel census of recreational anglers in the Wood River system, 1975-1976, Alaska Department of Fish and Game, unpublished). Most of this effort took place on Lake Aleknagik due to accessibility by boat and the close proximity of the village of Aleknagik. Although the system provides high quality angling opportunities for residents and non-residents alike, the northern pike is not a major target species of sport anglers. Emphasis at present is on rainbow trout, arctic char and salmon. The northern pike is only of minor importance.

Northern pike of the Wood River Lakes system are not exceptionally large and there are few pike exceeding the State's trophy fish minimum of fifteen pounds. The average sport caught northern pike in Lake Aleknagik in 1975 and 1976 was 520 mm (20.4 in) in length. Large northern pike were found primarily in small localized areas of Little Togiak Lake, Lake Beverley and Lake Kulik, only. These areas are relatively inaccessible at the present and have had insufficient angling pressures to crop what is probably a large standing stock of very old slow-growing northern pike. As human use of the Wood

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River Lakes increases, angling pressures intensify and knowledge of these localized "hotspots" for large pike spreads, these populations will certainly be in jeopardy. It is recommended that the sport fishing bag limit for the Wood River Lakes system may not contain more than one northern pike over 30 inches (760 mm) in length. An effort should be made to promote the northern pike as a highly desirable sport and trophy fish. Northern pike are found throughout the system, are available the year-round and are generally easily caught. Northern pike add variety to the already spectacular fishing available and provide tremendous opportunities to participate in fishing under highly aesthetic conditions.

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SUMMARY

1) Opercular bones were found to be superior over scales, otoliths, vertebrae and length frequencies as age and growth indicators of northern pike from Lake Aleknagik for the purposes of this study.

2) The problem of overlooking early annuli due to discoloration and increased opacity of large opercular bones was overcome by the use of the Walford plot.

3) Total length of northern pike from Lake Aleknagik was regressed on opercular bone length (projected images) and gave the relationship: $Y = 11.87 + 3.07X$ ($r = .9954$), where Y = total length of northern pike in mm and X = length of the opercular bone in mm.

4) Some age and growth differences of northern pike were detected between individual lakes of the Wood River Lakes system, as well as between three distinct areas within Lake Aleknagik alone.

5) The greatest increment of growth for northern pike from Lake Aleknagik occurs during the first year of life and remains relatively rapid until about age 4^+. At this point, the annual growth increment decreases to about 25 mm per year, remaining relatively constant thereafter.

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6) Growth of male and female northern pike from Lake Aleknagik was not significantly different.

7) Growth of northern pike from Lake Aleknagik was relatively slow when compared to the rapid growth exhibited by pike from Minto Flats, Alaska. Wisconsin northern pike at age 10^+ are almost twice as large as pike at age 10^+ from Lake Aleknagik.

8) Growth of tagged northern pike from Lake Aleknagik was very nearly the same as growth of non-tagged northern pike.

9) The length-weight relationship for 385 northern pike from Lake Aleknagik taken from June to August, 1976 was $\text{Log } W = -5.2458 + 3.0213 \text{ Log } L$, where W is weight in grams and L is total length in mm. Length-weight regressions for male and female northern pike were not significantly different and therefore pooled to give this result.

10) A regression of fork length on total length for northern pike from Lake Aleknagik gave the relationship: $FL = -5.458 + .9529\ TL$ ($n = 251$, $r = .9995$).

11) Pike habitat in the Wood River Lakes system was optimal when water was brown in color, relatively warm and shallow and contained dense stands of aquatic vascular plants usually rooted in a muddy bottom.

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Pike densities were greatest in littoral areas where all of the above characteristics coincided.

12) Aquatic vascular plants were the single most important characteristic of pike habitat, providing cover and sites for reproduction. Utilization of plant species by pike shifted as the summer went by and floral succession progressed.

13) Less than five percent of the total surface area of the Wood River Lakes system was considered summer habitat for northern pike.

14) Extensive test gill netting showed that few pike inhabited waters that were not included as summer habitat as defined by this study.

15) Tagging studies have shown that the northern pike of Lake Aleknagik are homing to spawning grounds in the spring and then remain relatively sedentary in nearby summer habitat at least until late August. Eighty-four percent (274) of all tag recoveries (327) indicated that pike remained in their original tagging location or returned there before recapture.

16) Tag recoveries indicated the absence of differential mortality as a result of the capture techniques which included gill nets, trapnets and sport angling.

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17) Large pike from Lake Aleknagik fed primarily on blackfish, threespine stickleback, ninespine stickleback and sockeye salmon during June, July and August of 1975 and 1976. Blackfish were the single most important food item increasing in importance from June until August when blackfish made up 45% and nearly 50% of the foregut contents by number and volume respectively. Threespine and ninespine stickleback were important food items in June and July but became insignificant by August.

18) Stickleback fry and mayfly nymphs were the most important foods of medium pike (50-199 mm) during the period July through September, 1976. Stickleback fry were more numerous but mayfly nymphs occurred more often in the foreguts of the pike examined.

19) The food of small pike (0-49 mm) included subclass Ostracoda (seed shrimps), Dipteran larvae, mayfly nymphs and unidentified fish remains.

20) Northern pike made up a small part of the diet of large and medium pike from the Wood River Lakes system.

21) The method of external sex determination of northern pike described by Casselman (1974) was used to correctly identify the sex of 266 (85.5%) of the 311 pike examined for this purpose.

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22) Control of northern pike in the Wood River Lakes system as a means of eliminating or reducing significantly the incidence of *Triaenophorus crassus* in sockeye salmon is probably not feasible.

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